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# Industrial Engineering


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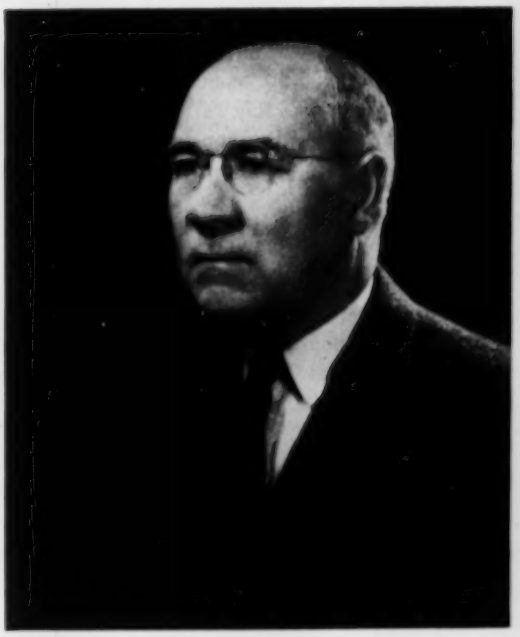
# PRESIDENT'S MESSAGE



## A Message to Local Chapters

**From Howard P. Emerson**

***President of the American Institute of Industrial Engineers***

Since our Annual Convention, I have been able to visit four local chapters. This leaves 57 more to go, if attempt were made to visit all of them. This is clearly impossible. Hence, the plan this year is for Regional Vice-Presidents to be the direct representatives of your National Officers in their respective regions. Whether a national officer calls upon your local chapter in the near future or not, there are certain proposals which your National Officers wish to transmit to you. I hope all officers of local chapters will read the following information and suggestions:

1. As of July 2, we had 61 local chapters, 30 student chapters with a total of 5420 members including 1330 student members. With your help we hope to increase all of these figures during the coming year.

2. The Executive Committee meets on the second Saturday of each month, with power to act on behalf of the Board of Trustees. Suggestions from local chapters can be sent to the president or to National Headquarters regarding any items for consideration at these meetings. Major policy decisions are made by the Board of Trustees, whose next meeting is October 13, 1956.

3. The Executive Committee has taken action on two questions that seem to have bothered members:

(a.) It has asked the Membership Qualifications Committee to restudy the status of affiliates.

(b.) National Headquarters is working out a plan for faster office handling of applications for membership.

4. Under a new rule, which went into effect July 1, local chapters are asked to notify their Regional Vice-President and the National Director of Conferences, regarding date and theme of conferences. The purpose is to avoid duplication of speakers or audience and to maintain high standards for AIIE sponsored programs. Experience of other chapters in running conferences can thus be made available to all.

5. It is suggested that each local chapter set up committees which might maintain contact with the directors or chairmen of similar committees on the national level. Such directors or committee chairmen, are as follows:

| | |
|---|---|
| *National Meetings* | Gerald Nadler (Director) Washington Univ., St. Louis, Mo. |
| *Programs* | Frank Johnson (Director) 863 Wellesley Dr., Atlanta, Ga. |
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| *Public Relations* | George Gustat (Director) Eastman Kodak Co., Rochester, N. Y. |
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6. The editor of the Journal, Bob Lehrer, would like to receive articles, suggestions, and criticisms regarding this publication. He has agreed to consider making one of the issues a directory of all of the members of AIIE. Adver-

tising for the Journal is solicited, but will be kept within 25% of total pages. We do not want advertising to dominate a technical journal of this kind.

7. Each chapter is encouraged to undertake a project of national interest as its contribution to AIIE. Some examples to date are as follows:

*Rochester Chapter*—Movie on Industrial Engineering

*Eastee Tenness Chapter*—Membership Qualifications Committee

*Columbus, Ohio*—Investigation of job clearing house for members

*Cleveland, Ohio & Atlanta, Ga.*—Courses to prepare for Registration Exams

*Atlanta, Ga.*—Journal of Industrial Engineering

*St. Louis, Mo. and Cleveland, Ohio*—Television Programs to interest High School Students in Industrial Engineering

8. The Louisville, Ky., chapter has published a Chapter Directory, with advertising, showing pictures of all of the members with their biographies. The advertisements paid for its cost. Any chapter wishing to try out this scheme should contact the president of the Louisville chapter, Charles Eldridge. John Guenthner compiled the booklet. Other original contributions by local chapters or individual members are encouraged.

9. The Board of Trustees encourages local chapters to affiliate with Engineering Councils and other engineering groups on community projects, such as encouraging qualified high school students to consider engineering as a career. An ECPD five year plan for assisting the young engineer in adjusting to his profession is another example of how AIIE can work with other engineering societies at the community level. The Professional Relations Committee under Alex Rathe can provide information and suggestions.

10. All members who have occasion to be in or near Columbus, Ohio, are encouraged to drop in to see National Headquarters and visit with our Business Administrator, Don Trenwith. The rooms are now air conditioned.

He asks that you send him promptly the names and addresses of new officers and committee chairmen. Your Regional Vice-President should, of course, also be informed.

11. In addition to use of the above channels of communication, letters of comment or suggestion directed to the president or any of the national officers, or to Don Trenwith, are encouraged. I personally will always be glad to hear directly from any member of AIIE.


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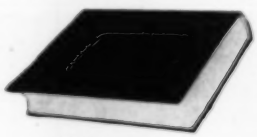

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Two-Strategy Games
Three-Strategy Games
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# The Role of Mathematics in Operations Research

**By Dr. Andrew Vazsonyi**

*Head, Management Sciences Research, The Ramo-Wooldridge Corporation*

What is operations research? This question has been with us ever since we began talking about operations research. Some people feel that operations research is something quite new, and has never been done before; some other people feel that there is really nothing much new about it, it is just an extension of current industrial engineering practices. Some people classify industrial work that they consider very good as operations research, and work that does not appeal to them as not being operations research. A lot of time and effort has been expended in answering this question, but the result is, generally speaking, frustrating. However, we should not be disturbed by this state of affairs; something new is being developed, and at this stage of the game it is to our benefit to have a variety of opinions.

There is, however, one aspect of operations research on which there is fairly unanimous agreement. This aspect is the use of mathematics in operations research. Suppose you are thumbing through a stack of magazines dealing with management problems. Operations research aims at the solution of management problems, and, therefore, let us assume that the *Journal of Operations Research Society of America* is one of the magazines. You will find a striking difference between the appearance of the *Journal of Operations Research* and the other magazines; operations research papers (perhaps not all of them) are full of mathematical equations. The other magazines on business, on the other hand, contain verbal descriptions. There are some people, of course, who say that there is too much mathematics in operations research, and that this is a weak point. This might be so. However, it is not premature to say that mathematics is here to stay in operations research. Perhaps as we go on the mathematics will become more simple and will be more understandable to the businessman; however, a good fraction of the papers on operations research will contain mathematics in the future, too.

A legitimate question on the part of the businessman is whether the use of mathematics is really necessary, or is mathematics used in business because scientists are used to employing mathematics in other fields? The purpose of this discussion is to prove that the use of mathematics in business is not a fad, but a sign of coming things. Not all operations research contains mathematics; not all business situations should be handled with the aid of mathematics. However, there are many business situations where mathematics makes it possible to describe and comprehend the fact of the business situation better than any verbal description can hope for. The fact of the matter is that mathematics is a language capable of describing certain business situations.

There is perhaps no other scientific subject in which there is so much confusion as in mathematics. Most of us have been exposed to certain aspects of mathematics in school, and have developed a healthy dislike and dread for the subject. Very few of us are proud of not knowing some particular subject, but mathematics is an exception. Again and again we meet people who keep emphasizing that they don't know any mathematics, that they will never be able to understand any mathematics, and that it is quite hopeless to try to teach them any mathematics. They seem to be quite proud of this state of affairs. This attitude is perhaps based on the deep belief that mathematics cannot be of any use in business.

On the other hand, there are some people who take a different attitude. They claim that business is full of numbers, business deals with profits measured in dollars, with costs again measured in dollars, etc. Therefore, mathematics should be quite useful in the business world. This is an argument that most mathematicians would face with a shudder.

The only way to understand the use of mathematics is to use it. This leads, however, to a vicious circle. What comes first, the chicken or the egg? Let us recall at this moment that certain mathematics has been beaten into all of us. Most of us know how to multiply and divide. You might say that this is not much mathematics. Our ancestors in the Sixteenth Century had a different point of view, as there were some universities that declared that all students would learn how to multiply, but the better ones will learn how to divide. If we go 2,000 years back, to the Roman World, we find that very few people knew how to multiply or divide. This should not suprise us, because if we tried to carry out a division with Roman Numerals, we would recognize that a genius is required to perform such an operation. Why do we know how to multiply and divide? Not many of us particularly enjoyed learning these operations in school; but we had to learn them because if we did not we would have flunked out in school.

It is entirely possible that the use of mathematics in business will take a similar course. As time goes on we will get more and more used to the idea that mathematics is useful. The things that look very difficult to us today will become second nature to the manager of a plant fifty years from today.

What is the reason that scientists have come to use mathematics? Let us spend a few moments in examining a problem of physics. Suppose we want to know how far a falling stone is going to go in a certain length of time. People who observed this phenomenon tell us that in one second a stone falls 16.1 feet, in two seconds 64.4 feet, in three seconds 144.9 feet, etc. Let us put this into table form:

| | |
|---|---|
| 1 second | 16.1 feet |
| 2 seconds | $4 \times 16.1 =$ 64.4 feet |
| 3 seconds | $9 \times 16.1 =$ 144.9 feet |
| . | . |
| . | . |
| . | . |
| $\frac{1}{2}$ second | $\frac{1}{4} \times 16.1 =$ 4.0 feet |
| . | . |
| . | . |
| . | . |

On the basis of this information we can compute how far a stone will fall in any length of time. The rule implicit in the table could be formulated in words, but let us not bother to develop this statement.

The situation of the falling stone can also be described with the aid of an equation. This equation can be written as

$$D = 16.1t^2$$

where $D$ is the distance, in feet, that the stone falls, and $t$ describes the number of seconds. You will readily see that this description of the problem is more precise and concise than describing the phenomenon with the aid of the table.

However, this is not all. Suppose we want to know how long it takes a stone to fall a hundred feet. Presumably you could work out the answer to this problem without mathematics. However, it is much simpler to write the formula

$$t = \sqrt{.06D}$$

which tells us the time it takes for a stone to fall a distance of $D$. If we want to get the answer for 100 feet we have to substitute 100 where the letter $D$ appears, take a square root and then we get the number that it takes 2.4 seconds for a stone to fall a hundred feet.

You see here that mathematics can help quite a bit in such a problem. The real advantage comes, though, when we deal with more complicated phenomena. In order to handle the problem with a verbal description, we need to construct a pyramid of arguments, which become more and more complicated and confusing as the phenomenon becomes more complicated. Pretty soon we get to the point that the verbal argument loses its usefulness, and all we have is a confused state of affairs. Mathematics makes it possible to economize in thought, makes it possible to deal with the problem in question effectively.

It is quite far-fetched to claim that there is a relationship between a falling stone and a business problem. We all know that business cannot be described with the aid of formulae; there are too many intangibles involved, there are different personalities, organizational problems, motives involved. How can anyone claim that all these things can be put into a formula?

In the case of the falling stone there are a great many things that were left out of the equation. What about air resistance? This will depend a great deal upon the particular shape of the stone, and the particular surface roughness. All these things are completely ignored in the formula; however, it is possible to develop a more elaborate formula for the motion of this stone. This formula would take into account air resistance, but probably even this would not take into account all the various ramifications of the problem.

A very similar situation exists when describing business problems with mathematical equations. Equations will always describe only certain aspects of the problem, and a great many things will be left out. The point, however, is this: the objections raised against using mathematics in business are quite similar to the objections that can be raised against using mathematics in physics, and, in fact, these same objections were raised hundreds of years ago in connection with physical problems.

Let us now stop talking about problems in physics and turn our attention to business problems. Imagine a hypothetical factory producing some rather complex assemblies, similar to airplanes or radar sets. There might be thousands of these articles produced on assembly lines and in machine shops. Imagine that master schedules for the shippable items are set well in advance, but are subject to periodic changes. We propose to illustrate the use of mathematics in business by showing how mathematical methods can help in solving some of the problems this factory might face. Certainly the manager of production control in this factory wants to know how many parts and assemblies he should manufacture to meet this particular shipping schedule. Also, he wants to know at what time he should manufacture these various parts. We propose to show that this problem can be described and solved with the aid of mathematical equations. We also propose to show that with the aid of mathematical equations it is possible to determine the machine and labor hours imposed on this factory by this particular master shipping schedule.

Systems of equations, or formulae, that describe a business problem are customarily referred to as the mathematical model of the business in question. The problem of how many parts are required to meet a certain shipping schedule is often referred to as the problem of parts listing. Therefore, we proceed now to establish a mathematical model; that is, a system of equations that describes the problem of parts listing in a manufacturing firm.

## A Mathematical Model for Parts Listing

The basic information required for production control is usually listed on so-called assembly parts lists. An example, shown on Figure 1, refers to a Panel with part number 435090012. This "Makes Assembly" is made up of seven different articles as shown on the parts list under the heading N.A.QTY. (Next Assemblies Quantity). It is shown how many of these articles are needed. Thus, the bushing part number 420990309 is required in a quantity of three for each of the panels 435090012.

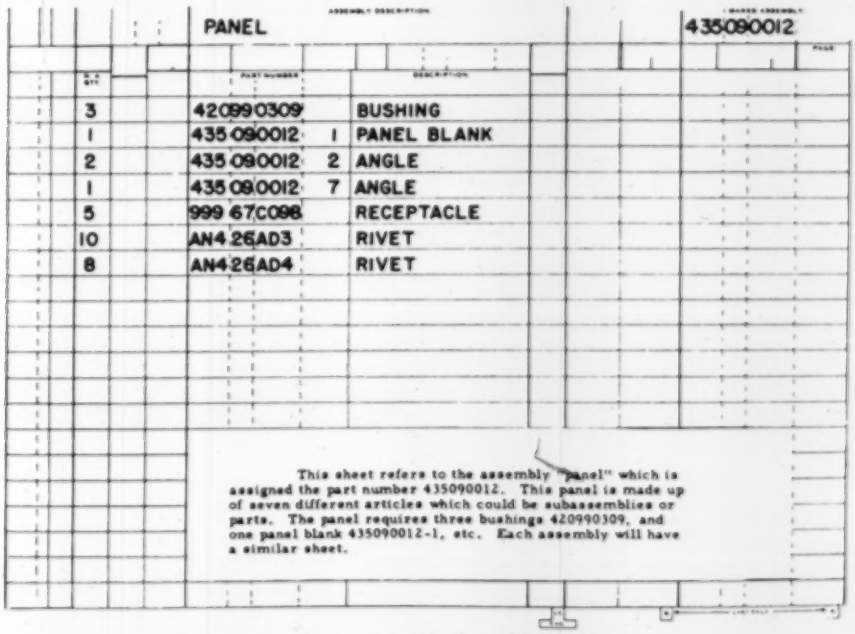
PANEL
435090012
3 420990309 BUSHING
1 435090012 1 PANEL BLANK
2 435090012 2 ANGLE
1 435090012 7 ANGLE
5 999 67C098 RECEPTACLE
10 AN4 26AD3 RIVET
8 AN4 26AD4 RIVET
This sheet refers to the assembly "panel" which is assigned the part number 435090012. This panel is made up of seven different articles which could be subassemblies or parts. The panel requires three bushings 420990309, and one panel blank 435090012-1, etc. Each assembly will have a similar sheet.

FIG. 1. Assembly Parts List

There would be a similar sheet for every assembly, and in our hypothetical factory there would be perhaps a few thousand of these sheets. Our first problem, then, is to put this information into concise mathematical form. Before we do this, it will be useful to think of this problem in terms of a graphical representation. Figure 2 shows a simplified situation with three top assemblies and a total of nine articles.

The Next Assembly Quantities are shown by the arrows on the figure. The various Next Assembly Quantities shown on Figure 2 are represented in a tabular form in Figure 3, and this Next Assembly Quantity Matrix is a concise mathematical representation of the information contained in the assembly parts list.[1]

For instance, it can be seen either from Figure 2 or Figure 3 that each Article 7 or $A_7$ takes two $A_5$'s directly. We use the word "directly" advisedly, as $A_7$ requires, in total, four of $A_5$, as $A_7$ requires two $A_1$'s directly and each $A_1$, in its turn, requires two of $A_5$ directly. We are, of course, interested to know how many of each article is required in total (directly or indirectly) for each other article. This information cannot be read directly from the Next Assembly Quantity Table, and our problem is how to determine these Total Requirement Factors from the Next Assembly Quantity Table.

Just the same way as we put the Next Assembly Quantities into a tabular form, we put the Total Requirement

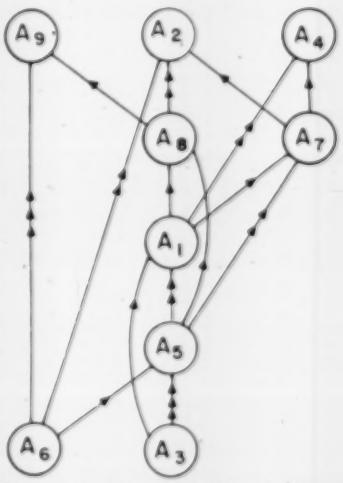


FIG. 2. The Gozinto Graph is a Pictorial Representation of the Parts Requirements. The next assembly quantities can be observed directly by counting the arrows on each connecting line. Total requirements cannot be observed directly but can be deduced.

[1] Note that we put "1's" in the diagonal. This makes the mathematical development easier.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 |
| 6 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 3 |
| 7 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

FIG. 3. Next Assembly Quantity Table. This is a concise mathematical representation of the information contained in the Assembly Parts Lists.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 3 | 0 | 3 | 0 | 0 | 1 | 1 | 1 |
| 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 7 | 33 | 1 | 27 | 3 | 0 | 13 | 10 | 10 |
| 4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 5 | 2 | 10 | 0 | 8 | 1 | 0 | 4 | 3 | 3 |
| 6 | 2 | 12 | 0 | 8 | 1 | 1 | 4 | 3 | 6 |
| 7 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 8 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

FIG. 4. Total Requirement Factor Table. Observe, say, the *second* column relating to $A_2$. The *third* element from the top in this column relates to $A_3$ and displays the number *33*. This means that *33* $A_3$'s are required (in total) for each $A_2$.

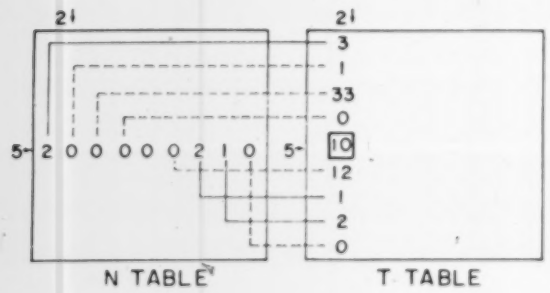


FIG. 5. Schematic Representation of the Equation

$$T_{5,2} = \sum_p N_{5,p} T_{p,2}$$

The second number of the fifth row of the $T$ Table equals the "scaler multiple" of the fifth row of the $N$ Table and second column of the $T$ Table:

$$10 = 2 \times 3 + 0 \times 1 + 0 \times 33 + 0 \times 0 + 0 \times 10 + 0 \times 12 + 2 \times 1 + 1 \times 2 + 0 \times 0$$

Factors into a table too.[2] To illustrate the case, Figure 4 shows the Total Requirement Factor Table associated with the illustrative example in Figure 2.

We agree that each $A_7$ takes four of $A_5$'s in total. In Figure 4, in the fifth row, under the seventh column, the number 4 is listed. The figure shows that 33 of $A_3$ is required for each $A_2$. Verification of this in Figure 2 requires a careful tracing of the various arrows. This tracing in Figure 2 can be described by the following statement:

Total number of $A_5$'s required for each $A_2$ =
(Number of $A_5$'s going directly into each $A_1$) × (Total number of $A_1$'s required for each $A_2$)
+ (Number of $A_5$'s going directly into each $A_7$) × (Total number of $A_7$'s required for each $A_2$)
+ (Number of $A_5$'s going directly into each $A_8$) × (Total number of $A_8$'s required for each $A_2$)

Note again, carefully, the distinction between the statement "total number of $A$'s required" and "number of $A$'s going directly into. . . ."

We proceed now to put the above statement into mathematical form. We denote by $N_{i,p}$ the Next Assembly Quantity, which indicates the number of $A_i$'s going directly into an $A_p$. Furthermore, we denote by $T_{p,j}$ the Total Requirement Factor, that is the total number of $A_p$'s required for each $A_j$. Then the statement above can be written as:

$$T_{5,2} = N_{5,1} \cdot T_{1,2} N_{5,7} \cdot T_{7,2} N_{5,8} \cdot T_{8,2} \qquad (1)$$

or

$$T_{5,2} = \sum_p N_{5,p} T_{p,2} \qquad (2)$$

A schematic representation of these two equations is given in Figure 5.

It is quite plausible now to believe that the above formula can be generalized for any pair of articles $A_i$ and $A_j$; therefore, we write that

$$T_{i,j} = \sum_p N_{i,p} \cdot T_{p,j} \qquad i \neq j \quad (3)$$

Our convention about the "diagonal" elements can be written as

$$N_{i,i} = 1 \qquad (4)$$

$$T_{i,i} = 0 \qquad (5)$$

Equation 3 can be written in a more concise form by using *matrix algebra*:

$$[T] = \left[\frac{I}{I - N}\right] \qquad (6)$$

where $[I]$ denotes the unit matrix. It can be seen then, that our first problem, the problem of *the determination of*

[2] Note that we put "0's" in the diagonal. This again makes the mathematical development easier.

*the Total Requirement Factors, leads to a problem in matrix inversion, as shown by Equation (6).* Or, to say it in another way, our problem is to solve the system of equations (3), (4) and (5) for the unknown $T$'s. If these matrices had no special property, it would be practically impossible to carry through this computational task for thousands of articles. Fortunately, most of the elements on the matrices are zeros and the matrix is "triangular" and, consequently, special computational procedures can be developed.

At this stage, we have a formula for determining the parts required for each shippable article. The next problem of determining requirements to meet a given shipping schedule can be handled relatively easily. Suppose we are shipping only Articles $A_2$, $A_4$, $A_9$, and $A_5$, the last being a spare. How do we compute the quantity of $A_5$'s required? Clearly

Quantity of $A_5$'s required = (Total number of $A_5$'s required for each $A_2$)
× (shipping requirements of $A_2$)
+ (Total number of $A_5$'s required for each $A_4$)
× (shipping requirement of $A_4$)
+ (Total number of $A_5$'s required for each $A_9$)
× (shipping requirement of $A_9$)
+ (shipping requirement of $A_5$)

In order to put this in mathematical form, we introduce the notation that the shipping requirements are given by $S_1, S_2, \cdots$ and that the unknown requirements for the articles are $X_1, X_2, \cdots$. With this notation the above verbal statement can be written as

$$X_5 = T_{5,2} \cdot S_2 + T_{5,4} \cdot S_4 + T_{5,9} \cdot S_9 + S_5 \qquad (7)$$

This equation can again be written as

$$X_5 = \sum_k T_{5,k} \cdot S_k \qquad (8)$$

Again, it is plausible to generalize for any article $A_i$:

$$X_i = \sum_k T_{i,k} \cdot S_k \qquad (9)$$

This last equation then gives a method of determining the quantity of each article required, once the $T$ matrix is known. It is important to recognize from the computational point of view that most of the $S$'s are zero, as usually only a small fraction of the articles manufactured are shippable.

### The Problem of Scheduling

So far we have concerned ourselves only with the problem of quantities required. Now we propose to introduce the time element. We will assume that our hypothetical factory operates in production periods, and we will assume that the shipping requirement is given, for each article, in each period. The question we propose to answer now is how many of each article are to be made in each period.

In every manufacturing process articles must be made in a certain technological sequence. By inspecting Figure 2, one can see that, say Article $A_5$ must be completed before $A_9$ can be started, as $A_5$ is required when $A_9$ is to be assembled. The question is, then, how long does it take to make $A_9$ and how much time should be allowed for making it.

Figure 6 represents a routing sheet for manufacturing a certain article; the various operations, standard machine

PART NAME: SEAL STATIONARY FUEL — NO. 53-12972

MATERIAL: NITRALLOY EZ OR 'G' MODIFIED 1½ RD — SHEET NO. 1 OF 1

| OPERATION | OPERATION NO | DEPARTMENT AND GROUP | CODE | STANDARD HOURS PER 100 MAN I | MAN II H | MACH. 2 | MACH. 22 |
|---|---|---|---|---|---|---|---|
| FACE, DRILL, REAM, ETC. | 10-4270 | 301-45 | 1002 | | | | |
| COPPER PLATE | 13- | | | PURCHASED | | | |
| DEGREASE | 14- | | | PURCHASED | | | |
| DRAW TO SPEC 501 | 16- | | | PURCHASED | | | |
| RECEIVE | | | | | | | |
| HARDNESS INSPECT | 23-6900 | 314-89 | 5508 | | 20 H | | |
| ROUGH GRIND ETC. | 30-2840 | 303-52 | 2404 | | 13 H | | |
| NITRIDE TO SPEC #1600 | 33- | | | PURCHASED | | | |
| FINISH GRIND FLANGE SIDE | 65-2840 | 303-52 | 2404 | | 15 H | | |
| MAGNETIC PARTICLE INSPECT | 90-6900 | 314-85 | 5612 | | 42 H | | |
| DEMAGNETIZE | 112-6900 | 314-89 | 5508 | | 01 H | | |
| STOCK | | 362- | | | | | |

FIG. 6. Typical Factory Routing Sheet

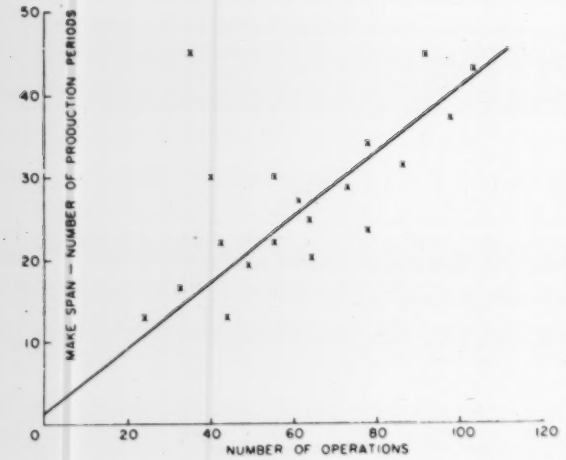


FIG. 7. Statistical Relationship between Number of Operations and Make Span.

and labor hours required are shown. However, the time required from start to completion is not shown, as further inquiry into the method of manufacturing must be made before this "make-span" can be determined.

Suppose first, that say, $A_8$ is manufactured on an assembly line. By a detailed analysis of the method of expending labor, and the time required between operations, the "assembly flow time" for $A_8$ can be determined. To this time one must add the time required to transport $A_8$ to the assembly line, which produces $A_9$; the total of these times is the "make-span" of $A_9$, and this is the time allowance that must be allowed when developing the production schedule.

On the other hand, suppose that $A_8$ is manufactured in a job shop; that is $A_8$ is manufactured in various lots, at various times. What should the make-span of $A_8$ be in such a case? It turns out that here the make-spans primarily depend on the number of operations required, as most of the time is spent by the lot "waiting" for the next operation. Such a situation is shown in Figure 7, where time required is plotted against number of operations.

In both cases, it is convenient to assume that there is such a thing as a *make-span* associated with each article. By combining these make-spans, it is possible to establish set-back charts as illustrated in Figure 8. It can be seen, for instance, that $A_9$ is allowed eight production periods, 5 periods of manufacturing $A_9$, and 3 production periods as a safety factor or "cushion." The set-back chart tells us that, say, $A_5$ must be started 19 production periods prior to the shipping day of $A_9$. If, say 100 of $A_9$ must be shipped in the 30th production period, then 3(100) of $A_5$ must be made in the 11th production period, as each $A_9$ requires a total of 3 $A_5$'s.

However, this is not all. $A_5$'s are also required for shipping $A_2$'s and $A_4$'s. If $A_1$, $A_7$, and $A_8$ are shipped as spares, there will be additional requirements for $A_5$. In order to handle this problem, we assume that a complete

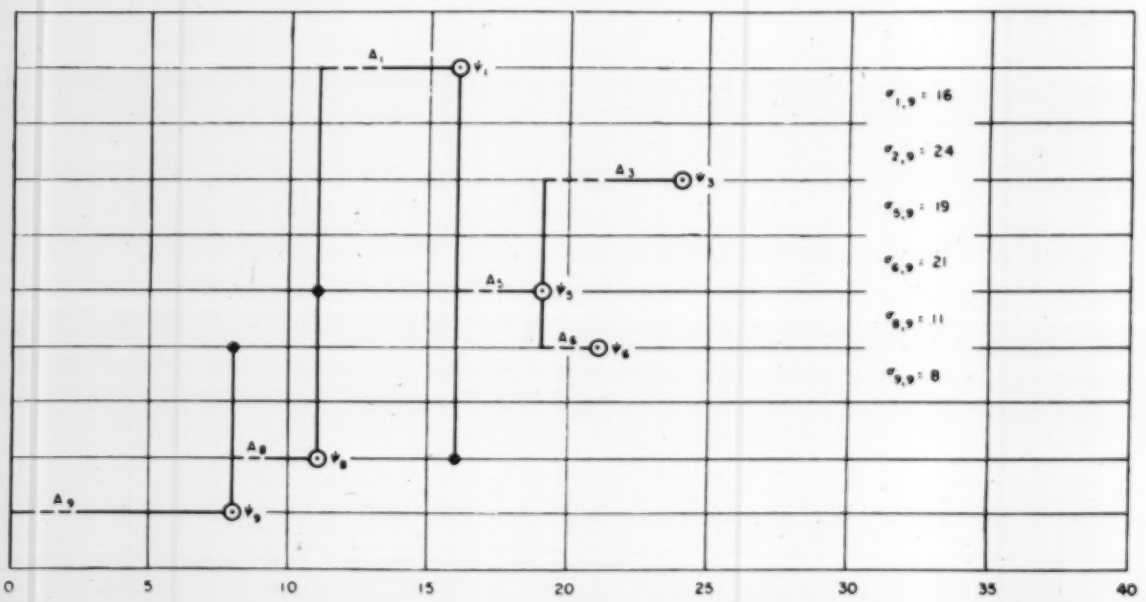


FIG. 8. Setback Chart in Assembly $A_9$ as an Example, the Setback of $A_1$ is 16

set-back chart is developed "in" each article (Figure 8 is the set-back chart "in" $A_9$) and that a set-back matrix, as shown in Figure 9 is developed, where each column represents a set-back chart. This table in Figure 9 shows, for instance, that in order to ship $A_2$'s, (second column), $A_5$'s (fifth row) must be made in advance of 18 periods.

Suppose now that the shipping schedules are given in tabular form as shown in the upper part of Figure 10, where each row refers to an article and each column to a production period. Suppose that the manufacturing schedules are to be developed as shown on the lower part of the figure. Let $s_k^m$ (the number in the *k'th* row and *m'th* column) denote the number of $A_k$'s to be shipped in the *m'th* period, and let $x_k^m$ denote the quantity of $A_k$ to be manufactured in the same period. Then, for instance,

$$x_5^{11} = 2s_1^{19} + 10s_2^{29} + 8s_9^{30} + s_5^{14} + 4s_7^{24} + 3s_8^{22} + 3s_9^{30} \qquad (10)$$

as shown schematically in Figure 10. A somewhat simpler schematic representation is shown in Figure 11, where the various shipping schedules are transposed or set-back so that the method of computation becomes *matrix multiplication*.

Let us denote by $o_{i,j}$ the set-back of $A_i$ *in* $A_j$; then this

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 | 15 | 0 | 16 | 0 | 0 | 10 | 8 | 16 |
| 2 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 13 | 23 | 0 | 24 | 8 | 0 | 18 | 16 | 24 |
| 4 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 |
| 5 | 8 | 18 | 0 | 19 | 3 | 0 | 13 | 11 | 19 |
| 6 | 10 | 20 | 0 | 21 | 5 | 0 | 15 | 13 | 21 |
| 7 | 0 | 12 | 0 | 11 | 0 | 0 | 5 | 0 | 0 |
| 8 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 3 | 11 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |

FIG. 9. Setback Matrix [$o$]. Each column represents a setback chart. For instance, the ninth column represents the setback chart shown in Figure 8.

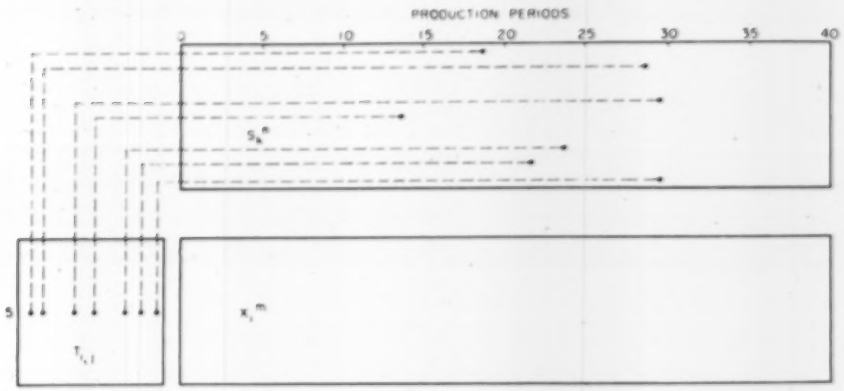


FIG. 10. Representation of the Scheduling Equation

$$x_5^{11} = T_{5,1}\, s_1^{19} + T_{5,2}\, s_2^{29} + T_{5,4}\, s_4^{30} + T_{5,5}\, s_5^{14} + T_{5,7}\, s_7^{24} + T_{5,8}\, s_8^{22} + T_{5,9}\, s_9^{30}$$

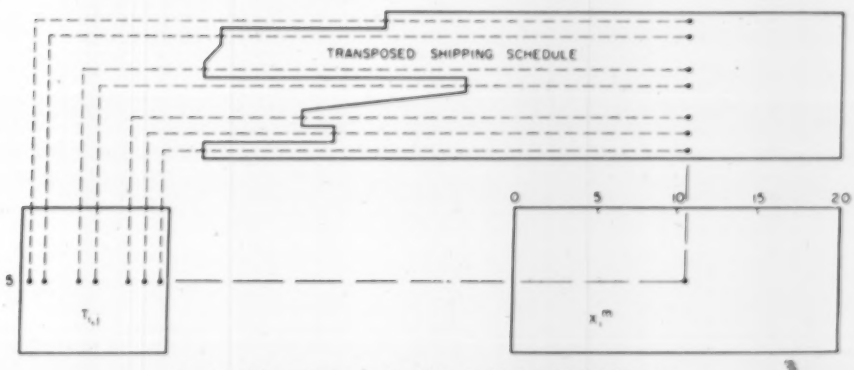


FIG. 11. Scheduling as a Problem in Matrix Multiplication

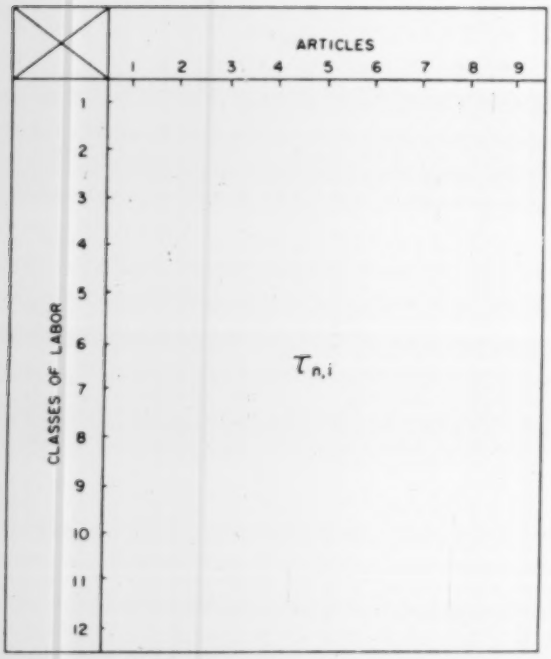


FIG. 12. Manhours Requirement Matrix

number is shown in the *i'th* row and *j'th* column of Figure 9. With this notation, equation (10) can be written as

$$x_5^{11} = 2s_1^{11+\sigma_{5,1}} + 10s_2^{11+\sigma_{5,2}} + 8s_3^{11+\sigma_{5,4}} + s_5^{11+\sigma_{5,5}} + 4s_7^{11+\sigma_{5,7}} + 3s_8^{11+\sigma_{5,8}} + 3s_9^{11+\sigma_{5,9}} \quad (11)$$

This same equation holds not only for the 11th period, but for any production period $m$ and so we can write

$$x_5^m = \sum_k T_{5,k} s_k^{m+\sigma_{5,k}} \quad (12)$$

Again, the equation holds not only for $A_5$, but for any article $A_i$:

$$x_i^m = \sum_k T_{i,k} s_k^{m+\sigma_{i,k}} \quad (13)$$

This last equation is our scheduling equation: *it relates the unknown number of articles to be manufactured to the given shipping schedule.*

## Machine Loading

Finally, we proceed to the machine hours computations associated with the schedule. We assume that each article is routed through a number of machines and that the standard times are available from routing sheets similar to Figure 6. This information is to be represented as a $\tau_{n,i}$ matrix shown in Figure 12, where $\tau_{n,i}$ denotes the number of hours required on machine type $n$ to manufacture article $A_i$.

The total labor hours required in production period $m$, on machine type $n$, is given by the *matrix multiplication* relationship

$$h_n^m = \sum_i \tau_{n,i} x_i^m \quad (14)$$

as shown schematically in Figure 13. When equation (14) is combined with equation (13) we get

$$h_n^m = \sum_i \sum_k T_{i,k} s_k^{m+\sigma_{i,k}} \quad (15)$$

This last equation relates the machine hours associated with the given shipping schedule.

In these formulae we neglected set-up time. If this is important, the formula can be modified by adding these set-up times. Man hour computations for assembly or other type of labor can be computed in a similar fashion.

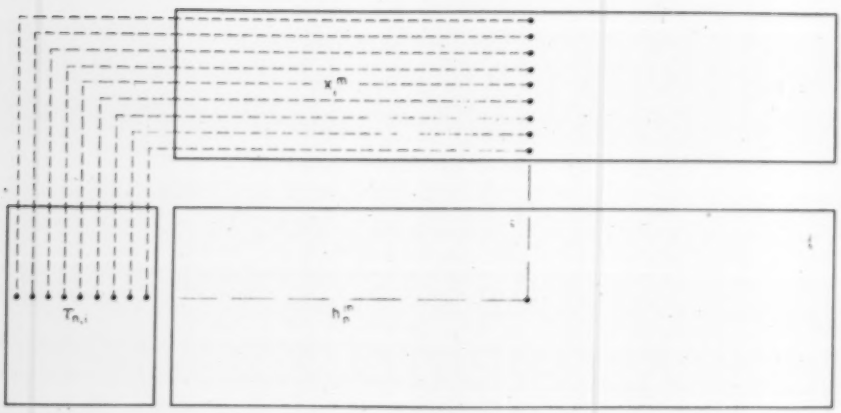


FIG. 13. Scheduling of Labor with Matrix Multiplication:

$$h_n^m = \sum_i \tau_{n,i} x_i x_i^m$$

In summary, then, we see that if a shipping schedule is given, equations (3), (9) and (13) allow the computation of the number of articles that must be manufactured in each production period; equations (14) or (15) allow determination of the machine hour requirements in these production periods. *All these equations are formulae from matrix algebra.*

**Advantages of Using Mathematical Model**

We proceed now to describe the advantages to be gained from the use of mathematical models in this or other management fields:

1. *A mathematical model indicates what data should be collected to deal with the problem quantitatively.*

In our particular case, for instance, the concept of set-backs is brought into focus. From the presentation one might think that this is quite a straightforward concept, and used by all manufacturers. The fact of the matter is that the concept is not usually used in a very clear-cut fashion. Different people in different plants, or even within the same plant, have a different notion of what these set-backs are. Such vagueness in concepts leads to a great deal of frustration and lost motion. The advantages to be gained by a common understanding as imposed by the mathematical model lead to significant advantages in production control.

2. *A mathematical model establishes indices of effectiveness and control.*

We can again refer in this particular case to the concept of set-backs. Once this concept is firmly understood, it leads to a method of control of a particular production department. As time goes on one can determine whether this particular department is improving or getting worse. Or, again, it is possible to compare various departments and see how their particular effectiveness compares.

3. *The mathematical model makes it possible to use mathematical techniques that otherwise appear to have no applicability to the problem.*

Who would have thought that matrix algebra is applicable to parts listing? The advantage to be gained by using a known mathematical technique is not to be ignored. We have found that when the detailed computational techniques for parts listing and scheduling are developed, known mathematical techniques from matrix algebra become of importance.

4. *The mathematical model makes it possible to deal with the problem in its entirety and allows a consideration of all the variables of the problem simultaneously.*

In our particular case, relationships were determined between the shipping schedule, the number of parts manufactured in each production period, and the labor loads imposed by this particular shipping schedule. If any of these production variables are changed, our equations permit the determination of the effect of these changes on the other production variables.

5. *The mathematical model is capable of being enlarged step by step to a more comprehensive model, to include factors that are neglected in verbal descriptions.*

There are many important factors that are left out of our mathematical model. For instance, we have not talked about inventory levels, accounts payable or accounts receivable. Let us stress here that the mathematical model presented here is only a beginning. We have found, however, that when dealing with specific problems it is possible to include these other factors by modifications of the mathematical model.

6. *The mathematical model uncovers relations between the various aspects of the problem which are not apparent in the verbal description.*

When we developed this mathematical model further, we discovered relationships between inventory levels and tightness of schedules. When set-backs are made large, large inventories follow, but the plant manager finds it easier to keep the schedule. On the other hand, when set-backs are made short, inventory levels go down, but effort and expense must be expended in keeping this tight schedule.

7. *The mathematical model prepares the groundwork for the introduction of large-scale electronic data processors.*

Electronic computers by their nature are machines that compute and perform logical operations, and, consequently, the problem of obtaining solutions through electronic computers can be greatly alleviated by the introduction of mathematical models.

8. *The mathematical model frequently leads to a solution that can be adequately described and justified on the basis of a verbal description.*

The mathematical model described in this paper uses such concepts as the Next Assembly Quantity Matrix, Total Requirement Factor Matrix, Set-back Matrix, etc. This does not mean, however, that the various operating personnel dealing with these variables must learn the mathematics of matrix algebra. These people usually deal only with certain zones of the problem, and it is usually possible to describe these various zones without using mathematical equations.

As a final note, may we point out that mathematical models perhaps should be compared with maps. Most of us use maps to find our way around when we travel. However, the multitudes of problems that beset us while traveling are not usually blamed on the maps we use. Mathematical models will become more and more important in business; they will help to describe and to solve management problems. However, a mathematical model does not necessarily include all the facts of a business situation, and we should not plan to obtain solutions to all management problems by "formulae".

# Overcoming Resistance to Change*

**By Gordon S. Mead**

*Manufacturing Engineer, North American Aviation, Inc.*

There is no doubt about it, overcoming resistance to change is a serious problem. Changes are the life blood of a continually growing organization. Auren Uris and Betty Shapin, in their book, "Working With People", devote an entire chapter to this subject. I think one of the best paragraphs I have read concerning the seriousness of this subject is in this book.

> Business cannot afford to remain static. Ever-present pressures, competition, shifting consumer demand, erratic prices and material shortages make change essential. Unless workers accept these changes, the company cannot adapt to the changed conditions—and the business that can't adapt—can't survive.

Changes are the life blood of a continually growing organization. All of us want to be a part of a growing organization.

The Coal Industry is a good example of what can happen when changes are not adapted. Once upon a time as the story might go, coal was the basic source of energy for both domestic and industrial use. This was a good many years ago. The introduction of gas, electric and oil and less costly sources of energy slowly changed this. Due to a lack of change, primarily in the method of mining and marketing, the industry's competitive position was weakened. But today coal is once again being recognized as a top competitor. Mechanical mining equipment which reminds one of a dragon chewing up stone can mine tremendous quantities of coal. Mechanization doesn't stop here—coal is removed from the mines in endless conveyor belts. An 108 mile coal pipe line ending in Cleveland, Ohio is planned that will cut transportation costs in half for industries in that area. Coal research is financed by the industry as a device to put coal back into the power picture. Changes in methods, through research, is one of the keys to their success.

## Resistance

When we speak of changes and overcoming resistance to them, I think we should agree that we are speaking more about the degree of resistance. In other words you and I are instrumental in making changes of one type or another every day. The more people they affect the greater the possibility of resistance. We are told by psychologists that all of us harbor neurotic fears which are always present, but in various degrees. Insecurity and anxiety always exist in the subconscious mind. As Auren Uris says, these are, "free floating, not attached to anything concrete and will seize upon something like a change to which to attach themselves." Our aim must be to have a better knowledge of all the factors and techniques which will help us to overcome resistance to change. Why? Well, it makes our job more fun. Also, and more important than that, it can create a working team that not only accepts changes but readily suggests them.

Before we go any further let us take a look at a definition I found of the Industrial Engineer and the qualifications he needs to meet today's industrial problems. He must be

> The intellectual amalgamation of a combined physicist and chemist who is professionally conscious of the value of a dollar; a mathematician who is willing to arrive at numerical results; a draftsman who prefers to sketch in free-hand style; a team worker who has in mind his own but can be convinced that there is value in the views of his confederates; and a reporter who can write in a clean, brief style. In addition, he will be more useful in his profession if he is an unhesitating public speaker. (*Author unknown*)

Complete? Well, surprising enough, with all the elements listed it is weak on the human element and the working relationship with the worker who does the work from the prints, and job instructions on the production floor or in the office. Although I had used this description many times in Industrial Engineering meetings, it wasn't until recently that I noticed the lack of emphasis on this important element. In line with this it also seems surprising to me that many of the best text books of time study methods do not dwell sufficiently on the factors of overcoming resistance to change. The authors are carried away with the techniques. Maybe this is as it should be, but I am inclined to think that many readers of these text books have a habit of overlooking this element too. To find the best material on this subject one must go to recent Industrial Management books. The field of psychology also has much to offer, for today more than ever many large and small companies are hiring psychologists in staff positions.

## Needs and Desires

In 1950–51 General Electric was apparently interested in knowing more about their workers. A survey established their following major wants and the importance of these wants:

* Based on a presentation at the Industrial Engineering Seminar at Cornell University on June 15, 1956.

1. Good pay
2. Good working conditions
3. Job security
4. Good bosses
5. Fair promotion practices
6. Respectful treatment
7. Full information
8. Belief in the job's importance
9. Job satisfaction

You will notice that the majority of these wants would require supervision whose technique in working with people most likely would equal or surpass their technical talents. A similar survey taken by the Labor Relations Institute of New York covering 24 large plants indicated similar wants. With this as a background I recently heard Mr. Merrihue, Manager, Employee Relations, of General Electric give a very appropriate talk concerning "A Company is Known by the Bosses it Keeps". May I ask—Is your personal human relations program geared to the wants of the workers of the company that is keeping you?

Let me, right here, inject another important element towards greater employee job satisfaction. Psychologists tell us that every individual possesses both physical and mental needs. They speak of it as the "Needs Concept". We are mostly familiar with the physical needs such as thirst, hunger and self protection. These are needs which can be more readily satisfied off the job. The mental needs are ones with which we may not be as familiar. The "Needs Concept" describes a mental need as an urge or desire which makes an individual say the things he says and do the things he does. The study of behavior patterns of an individual will indicate the intensities of his various mental needs. Those mental needs with which we are usually most concerned are: Assurance, attention, ownership, acceptance, status, association, assignment, integrity, attainment and relationship.

Providing a means for the employee to satisfy his particular needs should be one result of charting a needs pattern. Another result should be a greater understanding of the individual worker. With this increased understanding, for example, you are not likely to readily suggest changes in job methods to an employee who has a great need for assurance. (A need for assurance is that which makes a person plan for the future and do things which assure him of security). You will want a good approach as to how this suggested change will add greater security to his job. Where employee wants and needs patterns are most satisfied, the resistance to changes in methods are the least. Conversely, where these wants and needs are least satisfied, resistance to change is greatest.

Although Taylor is sometimes credited with introducing human relations in industry as part of his Scientific Management Movement, it is said by some that his only concern was human relations in terms of wage computation only. Dr. Raymond Villers in his book "The Dynamics of Industrial Management" states, "Taylor never thought of checking scientifically the workers' motivations, taking for granted that their very first, if not their only motivation was to earn wages as high as possible." Mr. Villers also states that a serious approach to human relations in industry was not made until the year 1945. He cites B. B. Gardner's book "Human Relations in Industry" as his example. The preface of Gardner's book states,

> Technological and economic logics are the concepts most commonly used in analysis of industry and these are the concepts in which future executives are usually trained. Unhappily, training in these logics is often assumed to be sufficient preparation for efficient performance as an executive. Many executives are impatient when it is suggested that they should concern themselves with the study of human relations. They believe that it is enough for them to understand the economics of the business to be proficient in analyzing the cost picture, to devise better equipment, or to improve sales. So far little has been written which would help either the executive or the student in his basic orientation to the human elements. It is for this purpose that this book has been written.

His revised edition published in 1950 indicated that a great deal had been accomplished in the previous five years.

Agreement as to the exact year when a serious approach to human relations in industry was made, is probably a good topic for discussion in itself. We can establish the fact that human relations as we know it in industry today is relatively a new experience. Mr. Gardner and others have no doubt helped many college boards to change their thinking as to what the graduate engineer should learn. A recent survey of Purdue University engineering alumni, relative to additional curriculum, suggested that the study of social sciences head the list. During the past six or seven years many engineering colleges have already extended their requirements to include social sciences such as philosophy, sociology and pyschology in fairly large doses.

**The Sales Approach**

In reviewing what others had done in this field of Overcoming Resistance to Change, I found that R. Tannenbaum of the University of California, L. A. gave a similar talk to an Engineering Institute several years ago. The title of his speech was Overcoming Barriers to the Acceptance of New Ideas and Methods. He emphasized three major techniques for overcoming recognized barriers. The first and the one we are all probably most familiar with is the sales approach. It should be one of the basic tools of successful industrial engineering.

I said it should be, but—A young man, who many thought had the makings for one of the company's better Industrial Engineers, was pinch hitting for his supervisor. The meeting he was attending was a review of a special training program to be given to a number of engineers throughout the organization. The Training Department had worked diligently for several months in cooperation with the supervision of the Engineering Departments. They wanted to be sure they touched upon those subjects that were thought most important. Everything went well until they reached the last subject—Sales. This was one of

his pet gripes. He literally jumped on the Training Department. He felt that the men who were to be given this course did not need the sales training. After all most of them had years of practical experience and many four or five years of technical training. They had the best answers. If anyone needed any training it was the plant supervision. They should be made to recognize the time and money being lost through their lack of acceptance of the engineer's ideas.

Incidentally, this young man no longer works with the company where this incident took place. He quit. No one would buy his ideas. Technically, was he a good engineer?

Another angle of this sales approach technique for industry is the written word. Dow Chemical Corporation published a pamphlet, "So You Don't Like Time Study—Well Who The - - - - Does?" To me this is a very excellently illustrated sales piece. It has an informal appeal to everyone in the business of making a living. In brief sentence structure it deals with price competition, manufacturing overhead, material and labor cost. It outlines how a company may expand from building mouse traps to furlined shaving mugs with musical chimes which play "Jingle Bells" on alternate Tuesday and Thursdays. Why? because there is a profitable market. Although it carries a copyrighted date of 1946 it is as up to date as today.

**Discussion**

Tannenbaum's second suggested approach, which he feels is better than the sales one, is another which many of you probably use today. You develop the new method in advance of approaching the employee. But you recognize that this first formulation is only a preliminary one. You welcome suggestions from all sources and make adjustments where better methods of operation are offered. This approach gives all who are affected an opportunity to add to or change the method before having to live with it. The workers so approached will undoubtedly build up less resistance to the change under these circumstances. They have had an opportunity to discuss their views. If they feel that an honest appraisal of their suggestions has been made, then the approach will have been a good one. But a word of caution. Have you ever sat around a meeting table waiting for the boss? The subject of the meeting has been announced in advance. Usually, one of the group can enlighten the others as to what the boss's thoughts are on this matter. As soon as some members of the group hear this, they mentally collapse. They are either thinking to themselves or out loud "if that's the way he wants it, then that's the way it will be." So the meeting is not as successful as the boss might think.

Each of us need a change of pace in our approach. You must not let those working with you get to the point that they feel they know exactly which way you are going to move and when. If you do, you will give many employees an opportunity to build stronger barriers of resistance. This in turn will cut off the ready flow of ideas, ideas that might be the real key to overcoming the problem at hand.

**Group Decision**

Tannenbaum's third suggested approach is similar to the previous one, but goes a step further. He calls it "group decision". The change is discussed and may be altered by better suggestions. However, the primary aim is to have the change in method brought about by the group. The group because of its participation and decision will back the change wholeheartedly. I think most of us will agree that of the three approaches, this last one is, generally speaking, the best. It was the one the speaker highlighted at that time.

Just like any other product of today's industrial progress this technique has been improved by others. Today this "group decision" technique has developed into what is called "consultative management". Norman R. F. Maier, University of Michigan, uses this term in his book "Psychology in Industry". In "consultative management" you start out with the fact that a change is needed and why. You don't work out a method or any new method in fact before you approach an individual or group. The only concrete fact is a change is necessary—"because". The more important the "Because" the more interested the participants can become. They are in on the ground floor. Any idea they offer will be better than the boss' (at least at that moment) because he has indicated he hasn't had time to sit down and give the matter careful thought. When you can develop a system of communications and confidence with the workers on the production floor or in your office that will set up a two-way flow such as mentioned here, then you will be putting human relations to work for the good of all. Furthermore, fewer employees will get the feeling that you are trying through devious methods to overcome their resistance to change.

There are at least two more important aspects to this type of approach. One, it takes a big man to admit to problems that have not been solved. Today industry is looking for this big man who can build an organization and get things done working with people. The other aspect has to do with the good atmosphere one creates. It will help to solve a multitude of smaller problems in addition to the large ones. Small problems nipped in the bud never have a chance to grow up.

Of the many techniques that exist to help the industrial engineer overcome resistance to change several solve the problem and overcome resistance at the same time. The "group decision" or "consultative management" approaches do this. In addition to these there are others such as Brainstorming, Role Playing and the Incident Process. These three complement each other in many ways.

**Brainstorming**

Several magazines have recently featured Brainstorming.[1] Although the name may be new, I recognized the

[1] This is a group approach to problem solving where ideas are not allowed to be ridiculed. The thought is that a bad idea or an impractical one may suggest a good one to someone else.

technique as one I was introduced to several years ago when working in an advertising department. At the time our sales program was at low ebb. The Sales Manager called a meeting of all home offices sales personnel as well as the advertising staff. He reviewed the problem and asked for suggestions. We spent the morning deciding what to do. In an afternoon session we brainstormed how it was to be done. The approach to the low sales was a sales contest. Nothing new, but the afternoon session produced a long list of ideas from everyone, the secretary on up. The ideas made this sales contest entirely different. One of the most interesting features was the tie-in of each and every worker in the plant. Teams were assigned to back salesmen in the field. Pictures were taken of the teams, they were signed by all in the picture and sent to the salesman. Each week someone on each team wrote a letter of encouragement to his salesman in the field. Believe me, when they say this approach can help better human relations, I agree. Whether it was the approach to the problem or the inclusion of everyone in the plant that made this venture a success, I don't know. Both were major factors. Sales in many areas hit an all time high. At the conclusion of the contest a national magazine carried a story of the activities.

**Role Playing**

Another of the conference type techniques is Role Playing. There are a good many variations. One of the most frequent is where the supervisor or others assigned deliberately take an opposite view in a discussion of a problem. To arrive at the best group decision, those participating, are in effect, challenged to explore all sides of the problem. The initial decision is either defended and strengthened or a new concept is established.

Another variation of this technique is to set up a situation. Then appoint two or three people to represent the characters as described in the situation. Let us say the problem presented concerns an unusual number of rejections. The situation as described represents a meeting of the production supervisor, the worker whose parts are being rejected and a quality control inspector. One of the appointed "role players" is given a prompting sheet. In this case it is the worker. The prompting sheet will give him a defense to the high rejection rate. The supervisor is challenged to make a good approach in correcting the situation.

The other members of the group listen. While listening to the "role players" they can mentally place themselves into any one of the three positions. This technique helps individuals remember that there is another side to the story. It will help them develop the habit of considering all sides of the problem before making an important decision. Role playing of this second variation requires, for best results, appointment of characters who have a knowledge of the problems encountered by the role they play.

**The Incident Process**

One of the more interesting techniques of this type is known as, The Incident Process. This can be used to best advantage among workers where an incident can be introduced similar to an actual problem that is in need of a solution. It is much easier for all of us to analyze someone else's problem. We get a feeling apart from the situation. The personal resistance is not present.

When using The Incident Process with a group an incident (case history) is introduced without the solution. The participants ask questions of the group leader regarding additional facts and then each is given an opportunity to present what they think is the best solution. After this is done the solution as listed with the problem material is read. The group can analyze this answer along with the others given. This type of meeting provides the participants the experience of seeing how others react to a given problem. It widens their scope of knowledge for possible solutions to the problems that may be facing them. It creates an atmosphere for group decision.

The Bureau of National Affairs, Inc., Washington, D.C. publishes material for The Incident Process. Their presentation has been primarily developed for use in training supervision and top management. The publishers list a number of very interesting features that are a result of working with this technique. Some of them are:

1. mental exercise for those who participate
2. systematic way of working out decisions is formulated
3. it pools skills and experience of group
4. develops more skill to distinguish between facts and opinions
5. provides practice in making decisions

"Manage", published by The National Management Association, carries a monthly article called, "How Would You Have Solved This?". It is written by Lloyd P. Brenberger and is what I would call another variation of The Incident Process. A problem is presented and the reader is given an opportunity to write his recommended solution and send it in to the author. The best answers are included in a subsequent issue of the magazine. There is no end to the variation of conference type techniques,—techniques that will help you to better understand human nature and maintain your attack on the problem of overcoming resistance to change.

**The Challenge**

The project engineer or supervisor who thinks he can solve all his problems, if he could just get off by himself more often and think things through logically, is not long for the job. Today industrial problems have become so complex that top management has established numerous staff departments for the purpose of aiding the production supervisor and others.

One of the challenges to the industrial engineer is the successful combination of the latest skills of mathematics, physical and social sciences to solve problems. A project assignment cannot be considered successful unless all

involved have a feeling of knowing what, why and how things should be done. In addition they must willingly do their part to see that it is done.

Whether you are in a position of direct authority or are considered staff, your challenge is to work with people on the production line, in the office and with supervision and management on all rungs of the ladder. This type of coordinated program brings to the worker the full benefits of the entire organizational structure—these benefits which have been provided by management to promote, encourage and maintain top production both in quality and quantity. If in your organization the elements of the social sciences are weakest, then directly or indirectly with other staff departments the industrial engineer should help to educate, develop and encourage the entire working force to participate.

Caution must be observed in applying these or any other techniques. Very seldom can one introduce new techniques and expect them to immediately solve all your problems. You must overcome resistance to these changes through careful planning and gradual introduction.

In the final analysis, however, the success of your personal human relations program to overcome resistance to change must start with yourself. You must be willing to accept changes without undue resistance,—set the pace. You must learn to listen attentively and objectively to the problems of others. You must have or develop a sincere desire to understand people and want to help them to satisfy their wants and needs.

# The Industrial Engineering Definition Dilemma

**By Bert H. Norem**

*Chairman, Department of Industrial Engineering, Syracuse University*

The industrial engineering branch of the engineering profession devotes more time to defining what it is than does any other branch. The other branches of engineering are not well defined but the members of these branches do not seem concerned about a definition. The members of the industrial engineering branch should not be criticized too severely for appearing overly concerned about a definition, however, for certainly it is good planning to determine the objective before trying to do the job. The criticism that may be justified is that we use the legitimate process of defining the objective as a means of warping or distorting the objective to fit our immediate position or set of circumstances.

Industrial engineering offers so many opportunities to be of service to mankind that we find ourselves bewildered by the choice of work. The concepts of Taylor, the Gilbreths and Fayol and the studies by Barnes, Porter, Carroll, Mundel, and many others leave us fascinated by the possibilities of finding better ways to do all kinds of things. We find that engineering and scientific methods are useful in the management of banks, hotels, retail stores, transportation, marketing, etc. Not only are the methods useful in these non-industrial fields but the compensation to industrial engineers doing such work may exceed that paid for doing engineering in industry. There has been ample reward to tempt the engineer out of industry to such activities. Perhaps this is one of the reasons we are so concerned about what our profession really is.

Recently the development of new mathematical tools and an up-surge in scientific methodology (mathematical statistics, electronic computers, operations research) has resulted in great activity in the area of scientific management. Since the graduate industrial engineer is reasonably proficient in the use of the new tools a large number of industrial engineers have been attracted to positions which permit them to use these tools in the most spectacular form. Most of the spectacular applications have been in non-industrial activities and some even in non-engineering activities. It is only necessary to examine the qualifications of the members of some of the successful operations research teams to show that this is true. The activity being worked on by the team may not be industrial and there may be no engineers on the team.

Many industrial engineers contend that operations research is merely industrial engineering discovered by persons who are not industrial engineers. Experience has proved that this contention has little to support it. Industrial engineers are usually qualified to be members of O.R. teams but O.R. is not industrial engineering. A way of showing the relation of O.R. to I.E. is to point out that O.R. tools are useful in doing I.E. work.

Operations Research is a name which expresses clearly the process of applying scientific methods in the analysis of and in the design of better operating practices. It is useful in many areas other than industrial engineering. However, while it is useful in industrial engineering, its most spectacular tools are not yet suitable for solving the majority of the relatively crude problems existing in most industries today. To use them in such crude situations is somewhat like measuring a 2" × 4" piece of wood with a micrometer.

Some persons with educations in industrial engineering have become so fascinated with the new mathematical tools that they have almost forgotten the work for which these tools were prepared. A still more disturbing development has been that persons with only the facility in use of these tools have attempted to teach and do industrial engineering work. This is an excellent example of "working in a vacuum." On the other hand, some graduate industrial engineers have become so interested in mathematics that they have started to work in this field. Such persons should be cautioned that they are competing with persons who have more education then they have in mathematics. They will be at the same disadvantage as a mathematician trying to be an industrial engineer. A person must have a good understanding of what industrial engineering is to avoid straying off into fields where one is at a disadvantage. This is not too difficult for industrial engineering has been well defined and its scope outlined.

**Definition**

Industrial Engineering is first of all "engineering" and as such is concerned with the "scientific utilization of the forces and materials of nature in the design, construction, production and operation of works for the benefit of men." Stated in another way, the engineer uses Methods, Materials, Money and Men in his accomplishments for the benefit of mankind. To do this requires that the engineer have an adequate basis of science (mathematics, chemistry, physics) and also that he have basic engineering courses such as materials, thermodynamics, fluid mechanics, electrical engineering, and design.

The second requirement of industrial engineering is that, as its name states, it be concerned with industry. This implies the application of engineering methods and practices to the production of goods. The profession of industrial engineering had its beginnings in the manufacturing division of industry and still has its greatest responsibility in this area. It is the engineering of manufacturing[1] and has as its important responsibilities:

1. The selection of manufacturing processes and assembly methods.
2. The selection of tools and equipment.
3. The design of the physical facilities of the plant, including,
   a. arrangement of machines and equipment
   b. the material handling equipment, and
   c. the materials and product storage facilities
4. The design of control systems for
   a. production
   b. inventory
   c. quality
   d. manufacturing costs, and
   e. maintenance
5. Cost reduction
6. Development of wage payment systems and job evaluation, and
7. Evaluation of performances.

[1] "Definition and Scope of Industrial Engineering", Bert H. Norem, News Letter, American Institute of Industrial Engineers, Vol. III, No. 2, April 1953.

**Process Design—A Responsibility**

Notable in the statement of what industrial engineering includes is "selection of manufacturing process." Probably the most important engineering work to be done in industry today concerns the design of manufacturing processes. This sounds uninteresting to many of us until we mention the word "automation." Even when we introduce the word automation there are many industrial engineers who are not interested. Manufacturing methods involve such a wide range of technology that we may actually be afraid of this area. There is so much to be learned that we shy away from it rather than accept our responsibility concerning it. We avoid jobs which would teach us more about processes when we go into industry. The present pattern will not help the development of I.E. as a fully recognized branch of engineering. We must reorient our course and choose that which best fits the needs of industry even if this means we must temporarily lay aside such fascinating ideas and tools as have recently been developed in mathematics. We must have persons with sufficient industrial experience teaching industrial engineering.

There are obviously more important reasons than "fear of the vast field of processing" that have caused us to neglect this field. One of the most important of these reasons has been the methods used to teach this subject in colleges. Traditionally, experienced shop men have been employed to take care of the processing equipment in our shops and to teach the student "how to run it." While this type of course has been interesting to the student and has given him some knowledge of manufacturing processes it has been an inefficient process and courses taught by persons without engineering degrees have rarely been of college caliber.

While it has been easy to criticize the teaching of manufacturing processes, it has not been easy to improve the methods used. The problem of up-grading the teaching staff or replacing it has been insurmountable in many schools. Still more important has been the problem of finding persons with the necessary education and experience who are willing to apply their talents in return for the compensation available at Universities. To handle the teaching in processing in an engineering college requires a more than average knowledge of science and engineering. It also requires someone willing to almost "go it alone" for a considerable period of time to develop the type of course and laboratory facilities which are necessary. Few persons with the qualfications are willing to make the sacrifice currently necessary to do this work.

With the increasing technology of manufacturing, engineers are being required to plan and develop the processes used. Industry is slowly learning the value of the engineer as compared to the experienced shop man for this work. When full recognition is awarded this field those qualified will be in great demand. This is real engineering work. It is the kind of engineering which Frederick W. Taylor

found of such great value in his day. The value of the engineer in the design of the manufacturing processes and plants is even greater today.

**Do We Want a Definition?**

Much of the confusion in arriving at a definition of industrial engineering or the unwillingness to accept a definition appears to center around the fact that the persons who want to be called industrial engineers are engaged in such a variety of work. Much of this work is in industry and is engineering but a large part of it is not in industry and even a good portion of that which is in industry is not engineering. Further, part of the work being done by the same individual will be engineering and the rest non-engineering work. It is easy to see why it is difficult to get agreement from a large number of persons in such an organization as the American Institute of Industrial Engineers on a definition of I.E.

The membership of AIIE is made up of engineers in industry, persons holding management positions in industry, educators, persons working for government, retail stores, hotels, banks, etc., consultants and many others with vocations too numerous to list. Each of these wants to be an industrial engineer and is more confident that he is one if what he is doing is called industrial engineering. This is to be expected. Each of us wants to have maximum recognition and being known as an industrial engineer is a form of special recognition. Every day the prestige of the title of industrial engineer increases because industry is learning what this new branch of engineering really is. Every day new doors of opportunity open to persons with Industrial Engineering degrees and industrial experience.

Another factor which contributes to the confusion in arriving at a definition of Industrial Engineering is the way we hold tenaciously to the title of industrial engineer when we move into positions of management, teaching, or other activities. We like to hold onto our original professional title. This is demonstrated in a related way by a number of industrial engineers who have moved into I.E. from other engineering branches. Many of these individuals still maintain, with pride, their membership in their original engineering societies such as A.S.M.E., A.I.E.E., etc. So, while we may receive advancement and more pay when we move into positions which are not engineering, we still want to be known by our professional title.

Consultants are faced with a peculiar dilemma concerning the practice of I.E. The I. E's. ability to handle a number of management jobs as well as engineering jobs, the temptation of the higher pay involved with the management work, and the direct benefit of extension of original contracts cause many consultants to work in Business Administration and Management fields as well as industrial engineering. A study of the work done by most consultants will probably show that a majority of it is of the Business Administration type. Yet, these consultants almost without exception wish to be called Industrial Engineers even if they do no engineering or may never set foot inside the doors of the manufacturing plants of industry.

Recently a group listed as the AIIE Long Range Planning Committee prepared a statement on Industrial Engineering which was published on the back cover of the November–December 1955 issue of the **Journal of Industrial Engineering**. This statement is as follows:

> Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials and equipment. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems.

This is a very broad statement of the work of the industrial engineer. It is difficult to think of anything which has been left out. Money appears to be the only important instrumentality used by engineers which is not mentioned. While this might be considered an adverse criticism, a more important criticism would probably be that the statement is equally applicable to all other branches of engineering. It is also a good statement of "operations research" and might apply to "scientific management." It is interesting to apply this statement by the Long Range Planning Committee to some activities quite different from engineering such as professional baseball or horse racing. The statement is an excellent example of what results when one tries to include everything that is done by industrial engineers and even by persons remotely associated with industrial engineering in a statement of what this branch of engineering is.

In conclusion it should be evident to all of us that we must think more clearly. We must push aside selfish motives if we are to have the benefits of a well defined and hence, properly recognized branch of engineering. We must stop acting like a herd of cows just released in a hitherto unpastured field, running all over trying to find the best place to eat but never having time to eat. It is "by our works we shall be known" rather than by all the things we can do. If we try to be recognized as everything we will end up with no recognition, for there will be nothing definitive or recognizable about us. The two words that make up our title are prestige words. Engineering is at an all time high in recognition. Industry is a name synonymous with our prosperity and well being. Together they can be the best known of all the names by which the engineering branches are called. But we must clear up our own confusion and try to be something instead of trying to be everything.

# The Additivity of Universal Standard Data Elements

By Elwood S. Buffa*

The purpose of this paper is to examine the current status of universal standard data, particularly with regard to the characteristics of additivity of the times for standard data elements. The basic thesis of this paper is that the question of additivity has not been answered, because most of the experiments which have been performed have not tested the hypothesis of additivity at all, but have tested the hypothesis of correlation or interaction between elements (1, 13, 19, 20, 21, 22, 23, 24). Inferences of nonadditivity have been drawn from these experiments. There are two studies known to the author where additivity was actually the hypothesis under test, and these are the experiments performed by D. E. Stiling (26) and by Ghiselli and Brown (11). The implications of the above studies of element interaction and additivity will be discussed below.

Universal standard data is a system of standard times for elements of motor activity, such as reach, grasp, position, etc. These elements of motion are assembled into a manual cycle by analyzing the motor elements required to perform the cycle. The objective is to predict the standard time for the cycle. If "standard" individual element times are represented by $t_i$ and the cycle time by $T$, then, $T = \Sigma^i t_i$. Additivity of the elements means that the expected value of the cycle time is equal to the sum of the expected values of the individual elemental times, or $E(T) = E(t_1) + E(t_2) + \cdots E(t_n)$. The value of a workable standard data system is that cycle times could be predicted if the required motion pattern could be synthesized and if the additivity hypothesis holds. Motion standard data systems have been proposed and are in limited industrial use for predicting production standard times used in production scheduling, the comparison of alternate manufacturing methods from the viewpoint of labor costs, the development of new equipment designs, and wage incentives. The validity of such data is important where it is used in mathematical models.

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The validity of the standard data concept leans heavily on the hypothesis of additivity of the elements. Dissenters have based their contention of nonadditivity largely on the evidence that the times for motion elements were dependent on the elements of motion which precede and follow the element in question (or in other words, element times are not independent), or that they are correlated. This paper will present arguments that element correlation is relevant in predicting variances of cycle times but is irrelevant in predicting mean cycle times.

The balance of this paper is organized around a discussion of the pertinent research which has been performed by engineers and psychologists in isolating the variables which affect element times, the interactions which occur and their magnitudes. Other investigations which examine the comparability of standard data systems (i.e., Methods—Time Measurement, Basic Motion Time Study, Work Factor, etc.) will be examined briefly. The question of additivity will then be taken up, and finally an experimental design for the testing of the hypothesis of additivity will be presented.

## Basic Variables and Interactions

Early work in the isolation of variables and interactions in motion elements was done by Dr. Ralph M. Barnes and his associates working at the University of Iowa. Dr. Barnes' objective was not to test the hypothesis of additivity, but to isolate variables and their effect. The series of experiments performed at Iowa and reported during that period indicated that distance, direction of motion, conditions for grasping, and path were among the variables affecting the time required to perform individual elements of motion. Most important in terms of the present discussion was the appearance of interaction between element times; that is, if distance was manipulated as a variable, the time required for the travel motions varied as would be expected, but the time required for grasping was also affected. Interaction appeared in all of these studies to a greater or lesser degree (2, 3, 4, 5, 6, 7).

More recent studies have merely tended to corroborate the general results of the Iowa studies in this respect. K. U. Smith, a psychologist working at the University of Wisconsin with collaborators, has produced recent studies

which bear significantly on the issue. Smith's studies used highly precise electronic time measuring equipment and sound experimental designs. In one experiment designed to determine the effects of laterality and movement direction (20), it was found that right handed subjects were superior to left handed subjects in both manipulation and travel time, and that travel times were faster for vertical than for horizontal patterns of motion. (Results were statistically significant.)

Another study (21) was designed to determine travel distance effects. The results of this study indicated that distance is a variable in travel motions, as would be expected from previous studies. The authors state that their results contradict earlier studies of travel distance effects in that previous studies have indicated that travel time did not vary with distance. Since they give no specific reference other than Barnes, *Motion and Time Study*, it must be assumed that they are referring to the Barnes study which reported that distance was a variable but that time was less than directly proportional to distance. These results could hardly be construed as indicating that distance was not a variable. Also in the above study Smith found significant interaction between travel and manipulative elements. Unfortunately, however, he indicates an unawareness of previous studies which showed motion elements to be correlated.

In a third study by Smith (22) an experiment was designed to determine the effects of complexity of motion pattern. The task consisted of turning a series of rotary switches. Changes of direction in the pattern of the switch turning task were introduced to achieve "complexity." It was found that "complexity" does not affect either the manipulation or travel times. The learning effect was significant for both manipulation and travel times, being small for travel time but 30 per cent for manipulation time. The conclusion was that "complexity" merely makes a task more difficult to learn. Smith then stated that this conclusion contradicts one of the principles of motion economy—"One of the commonly stated principles of motion economy is that the less complex the movement, the more efficient it will be." This author has searched high and low and can find no such principle. Perhaps Smith is referring to the principle which states roughly that movements should be kept to the lowest classification, i.e., fingers, hands, wrists, forearm, upper arm, etc. If he was, however, the present writer cannot see any connection between the above principle and the experiment performed. In addition, the definition of complexity seems poor, and hence this may make the results with regard to complexity inconclusive. Significant in this discussion is that the above study reported a correlation between the manipulation and travel times of 0.29 (significant at the 5 per cent level).

In still another study from the Psychological Laboratories at the University of Wisconsin (23), the components of movement in an assembly type operation were investigated. In this motion pattern the subject was required to grasp a part, move, position and release it and finally reach back to the supply of parts. Intercorrelations between elements were reported as follows:

*G* and *TL*, not significantly different from zero
*TE* and *G*, not significantly different from zero
*TL* and *P*, not significantly different from zero with three days practice, otherwise −0.30 at the 5 per cent level.
*P* and *TL*, −0.45 to −0.30 (reduces with practice)
*TE* and *TL*, +0.70 to +0.80
*P* and *G* not significantly different from zero.
*G* = Grasp, *TL* = Transport Loaded, *TE* = Transport Empty, *P* = Position.

These results indicate that correlations may exist only for some elements, perhaps between difficult manipulations and adjacent elements. The high correlation between *TE* and *TL* is undoubtedly largely due to the fact that both elements are strongly correlated with distance.

In another experiment (24), Smith used a pattern of rotary switches and varied the extent and direction of manipulation. Switches were turned 40°, 80° and 120° in both clockwise and counterclockwise directions. The pattern of motion was otherwise constant for all 6 conditions. Again, interactions were present. Both manipulation and travel times were found to be a function of the extent of manipulation. As the extent of manipulation varied from 40° to 120°, travel time varied nearly 10 per cent.

Another study by Smith examined the effects of sustained practice on motion elements (25). In these experiments the subject was given an initial practice of ten training trials each day for six consecutive days. For sustained practice effects, the subject was given four trials at a time once per week for eight weeks. As in the previous experiments, the task was a knob turning task in which manipulation and travel times were measured. During the initial practice a considerable learning effect was observed for manipulation times, and a much smaller learning effect for travel times. During this initial period, the standard deviation for travel times remained nearly constant but was reduced considerably for manipulation times (2.92 to 1.34). During the sustained practice period,—"There was a striking uniformity of mean times for both manipulation and travel times." The standard deviation for manipulation time remained nearly constant in this case, but the standard deviation for travel time dropped significantly over the period (3.02 to 1.97). Apparently initial learning is concentrated on the manipulative elements, as evidenced by the improvement in the consistency of manipulation times during this period. Perhaps the subject, or operator, masters the manipulation first and then concentrates on travel elements. A particularly interesting result of this study is that the correlation between manipulation and travel times is not materially altered by practice. During the initial practice period, $r = 0.41$ for the first day and $r = .51$ for the last day. During the sustained practice period, $r = 0.41$ for the first week and 0.46 for the last week. These correlations were all termed significant, but on all other days and weeks the correlations were not sig-

nificant, but on all other days and weeks the correlations were not significantly different from zero. Apparently correlations are not always present.

A final study reported here which was performed at the Wisconsin laboratories was done by Simon and Smader (19). In this study the objective was to determine the role of visual discrimination in motion cycles; i.e., if the task requires the subject to discriminate visually between objects, what effect does this have on the motion pattern, cycle times, individual motion times, etc. The subject grasped a washer from a bin and placed it on one of 12 upright pins. On half of the trials the subject placed the washers on the pins with red dots up and on the other half the washers could go on any way. Three travel distances were used. The distance variable produced significant differences in Transport Empty and Transport Loaded, but did not affect either Assemble or Grasp, and the interaction between discrimination and distance was not significant for any of the component movements. The addition of the discrimination condition increased Assemble by 15.1 per cent, Grasp by 7.7 percent, Transport Empty by 4.5 per cent, and Transport Loaded by 12.3 per cent. All of these increases were significant at the 1 per cent level, and highly reliable for days. It is well to note, however, that this experiment cannot be credited with determining the effect of "discrimination" alone, for the design of the task did not allow this to be measured. It is obvious to anyone that the task requires extra manipulatory motions to orient the part for the "discrimination" condition. This in itself would extend the time for some of the elements. Interaction could explain some of the increases in other elements. It is not clear from this experiment what the role of discrimination is. In order properly to determine the effect of discrimination, a task must be designed where the motion pattern is *identical* for the discrimination and non-discrimination conditions.

A great deal has been added by the work of the psychologists at Wisconsin, in spite of the exceptions noted. It is unfortunate, however, that some earlier work has not been recognized by them and that certain principles have been misconstrued.

Still other investigators have found interaction. Abruzzi used the Wilks Multivariate Test of Independence to determine if hand motions were correlated (1, Chap. 12). The test was made for single operators and cannot be construed to represent population data. He found that correlation existed between therblig elements for some operators.

Nadler and Denholm performed an experiment in which subjects had to reach to and manipulate rotary switches (13). They too found interaction between elements.

From the multitude of studies described briefly above, it is evident that element interaction has been demonstrated. It is useless to deny a fact which is evident in so many studies done by different people in many places. Industrial Engineers should accept it.

In all of the above studies the basic hypothesis under test was interaction or correlation, not additivity. Many have concluded from this evidence that motion standard data could not be additive. Gomberg particularly draws on some of the above work to make his case for non-additivity (12).

### Effects of Pacing

Due to the rapid advance of mechanization and line production, a growing proportion of operations are paced by a machine or conveyor. Surprisingly, however, very little work has been done to determine what effect pacing has on motion elements. This writer has been unable to find experimental evidence indicating standard data elements used widely in unpaced work have any validity whatever in paced work. Since these data were all developed from unpaced operations or laboratory tasks, it seems reasonable to expect that such data may be applicable to unpaced conditions. Paced conditions, however, present a different problem which may possibly demand data drawn from paced operations (accepting the workability of the standard data principle for the movement). Such meager data as is available indicates that motion patterns change and different elements speed up differently as load is increased. Siddall, a British psychologist, made film studies of a paced operation consisting of putting cardboard cylinders over bottles coming down a conveyor. He analyzed four motions—grip, move out, push down and move in. He noted the following variation of these elements with total cycle time (18):

1. "Grip" may take up to 18 times longer than it does most frequently.
2. "Push down" occupied an almost constant proportion of the cycle.
3. "Move out" and "move in" occupy a decreasing proportion of the cycle as the cycle time decreased.
4. At constant cycle time there was still wide variation in the time required for each of the four elements. This variability was still retained when the cycle time and one element were held constant.

The results indicate that the pace level has a significant effect on the time for individual elements. It seems highly likely that standard data elements gathered from original unpaced conditions might be in considerable error if applied to paced conditions.

Further insight into the effects of pacing is gained from two studies performed in England by Conrad and Hille (9) and Conrad (8). In the first, Conrad and Hille studied a packing task under both paced and unpaced conditions. They addressed themselves to three main questions:

1. What is the nature of the distribution of cycle times if the work is unpaced?
2. Is output adversely affected if operatives carry out a complete cycle when paced at their mean unpaced rate?
3. Is output adversely affected when the cycle is divided between two operatives under paced conditions?

The results of this study showed that for unpaced conditions, the mean cycle showed no significant change in

length throughout the day, but the coefficient of variation increased consistently and without exception throughout the day from 0.19 to 0.22 (significant at better than the 0.001 level). A similar result has been found in Radar Tracking (28). In heavier kinds of muscular work, where mean output decreases with successive trials, relative variability also decreases (27). This suggests that fatigue is manifested by increased variability rather than increased mean time in light work, and by increases in both of these measures in heavier work. Under paced conditions with one operator working at a pace equal to his mean time, output was as good as for unpaced conditions. When the cycle was divided between two operatives, however, output fell by about 12 per cent. Of course the reason for the fall in output is that both operatives have a coefficient of variation which on some cycles results in a shorter time interval in which the work is available to the second operative. Therefore, work is not always completed and the output of completed units falls. If the level of pacing is reduced so that all units may be completed, the result is still a lowered output. Conrad and Hille argue that based upon these observations:

1. When mean cycle time and distribution are constant, increasing belt speed will decrease output.
2. When cycle time and belt speed are held constant, an increase in the coefficient of variation of the operative will decrease output.

The results of Conrad and Hille would further question the use of standard data to predict the output of operatives in production lines. Mean element times tell only part of the story, for variability must be known in order to predict output. This problem is similar to the problem of machine interference which occurs when an operator attends more than one machine. Since an operative's coefficient of variation increases over the day, the problem is further complicated. None of the present proposals for standard data systems give data on the variability of elements.

In another paper Conrad further elaborates pacing effects on output (8). He discusses "systems with margins" i.e., the operative can reach ahead or wait until the part passes, rigid systems where the operative must meet a machine cycle, systems with queues, and operative to operative systems. In all cases predicting output is more complicated than simply knowing the mean speed of the operative as might be predicted from current proposals for standard data systems. In general, output is dependent upon the machine cycle time, the operatives' mean cycle times, the operatives' coefficients of variation, and the amount of time during which items of work are available to operatives.

## Comparability of Systems

A number of authors have based an attack on standard data systems on comparisons of the movement times given in the data tables. One of these used a carefully thought out experimental design to test the hypothesis that the data of three systems was comparable (10). H. O. Davidson used a paired comparisons statistical technique and found the differences in the three systems to be statistically significant. (Work Factor, MTM, and Holmes.) There is no question being raised about this result, but there does seem to be a logical question to be raised about the implied conclusion, i.e., that therefore the three systems are different in the predictions that would be made for cycle times. This approach to determining if they are different overlooks the fact that the data compared are not necessarily meant to be comparable. The breakpoints between elements used in the collection of the data could very well account for major differences, particularly in the shorter elements. In addition, no indication is given that adjustments were made for differences in performance level of the different systems. This approach of comparing element times also ignores the large element of art and judgement known to be important in the construction of a predicted cycle time based upon standard data of any kind. It would seem that a sounder approach would test whether or not differences in predicted cycle times are significant. In this situation breakpoints between elements should not affect the results, and the art and judgement required to derive a cycle time are included. Another study (16) plots a series of surfaces for the different elementary motions to show that element times for different systems are different at different magnitudes and control points. This crude approach to testing a hypothesis already well established by Davidson's study seems to add no new knowledge, particularly in the light of modern statistics and experimental design. The study gives no significance levels for the differences shown. Apparently, the differences are to be seen and judged to be different for the surfaces would show up well on slides.

Osmo Piispanen studied the differences between predicted cycle times for one and two handed work, using cycle times predicted by MTM, Work Factor and Basic Motion Timestudy (15). On the basis of paired comparison tests and other comparisons, he concluded that the results produced by the three systems were significantly different. Piispanen's study made adjustment for the differences in performance level of the different systems. The basic conclusion is still that the several systems are different as Davidson suggested, but it is based upon a reasoning process which seems more appropriate.

## Implications of Additivity

As mentioned earlier two studies have been made where the hypothesis under test was additivity. The first is reported in Ghiselli and Brown (11) and concerns a key tapping task. The keys were arranged in a pattern shown below:

A D F
B C E

Subjects were instructed to tap them in a certain sequence and the time required for each pair of keys was

recorded. Some of the keys were then eliminated from the pattern and a comparison was then made between the actual time for the reduced cycle and the time that would be predicted by the appropriate element times in the first sequence. In two examples with different patterns the results were as follows. In the first example, the actual time for the reduced cycle was 1.81 seconds and the expected cycle time was 1.71 seconds. In the second example a different tapping sequence was used; the actual cycle time was 0.62 second and the expected cycle time was 0.71 second. A logical conclusion to draw from these results is that additivity does not hold for the conditions of this experiment, but the description of the experiment does not indicate the number of subjects or significance levels. Stiling (26) discusses this experiment, however, and states that only one subject was used and that no statistical analysis of the data was available for the experiment. Under these conditions it would seem appropriate to weight the results of this experiment very lightly. Stiling also points out that when keys were eliminated in the pattern, the direction of motion changed. Direction change is a fairly well established variable in the time for travel motions (3, 14). In addition, direction of motion itself has been found to be a variable (5). This is illustrated clearly if the key depressing patterns used are examined (see Figure 1).

A second study where additivity was the hypothesis was done by D. E. Stiling (26). Twenty-four subjects performed a simple task which involved travel and manipulation motions in aligning a pointer to a scale marking by means of a rotary knob (see Figure 2). In the first task five such dials were manipulated. In the second task one of the dials was left out of the sequence, in the third task two dials were left out of the sequence, and in the fourth task three dials were left out. Two levels of alignment difficulty were used. The basic hypothesis was tested by predicting the times for the successive reduced cycles from measurements made in the complete cycle, and comparing these predictions with the actual times taken for the reduced cycles. The conclusion was that the differences between the actual and estimated cycle times was completely explainable as chance variation, or, additivity held for the

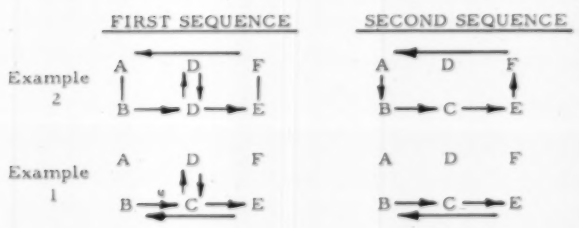
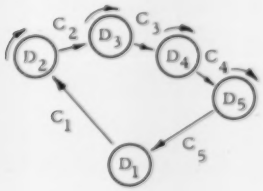



FIG. 1

TASK I: ALL FIVE DIALS USED.
FIVE MANIPULATIVE MOVEMENTS.
FIVE CONNECTIVE MOVEMENTS.




TASK II: DIAL No. 2 ELIMINATED.
CONNECTIVE MOVEMENTS $C_1$ AND $C_2$ ELIMINATED, $C_6$ SUBSTITUTED.

TASKS III AND IV ELIMINATED DIALS 3 AND 4 RESPECTIVELY.

FIG. 2. Stiling's Task Design

conditions of the experiment. (Significant at the .001 level.) One might point out in this experiment that the motion pattern was not complex, although the task did require some manipulation. Also, it may be seen by examining Figure 2 that direction of motion was a confounded variable since the direction of the first travel motion changed with each successive reduction in task.

We now have the perplexing situation where one study points toward additivity and one does not, although the key mapping study must be weighted lightly. Neither of the studies has tested the hypothesis under a variety of conditions, although the Stiling study used two levels of alignment difficulty. It seems evident that the question has not been resolved by these two studies since they disagree and because neither study has tested the hypothesis for a complex motion pattern, under paced conditions, for different distances of travel, under bi-manual conditions, etc.

Probably the most interesting inquiry into the subject of additivity was made by Alan J. Rowe in his paper, "An Analysis of the Applicability of Standard Data for Production Scheduling" (17). He points out that the average or expected values of elements may be added up to yield the expected value for the cycle time based on these elements so long as the elements themselves may be considered random variables. In other words, if we have three random variables $x$, $y$ and $z$ with a joint density function $f(x, y, z)$, then the expected value of their sum is equal to

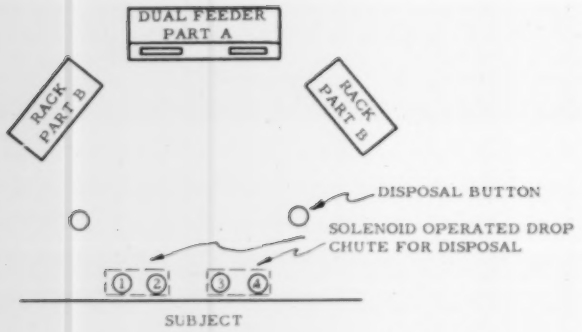



FIG. 3

the sum of their separate expected values, thus $E(x + y + z) = E(x) + E(y) + E(z)$. This is true regardless of dependence or correlation between the variables. Applying this to standard data, expected values would be determined for elements of motion under various conditions, i.e., for reach motions, different distances, different conditions for motions which follow and precede, different sequences, etc. Then expected values for cycle times could be determined by adding directly the values of the appropriate motion elements, as measured in cycles parallel to that for which the cycle time is to be predicted. In other words, element interaction or correlation may be present without affecting the basic additivity of the elements. As Rowe points out, "Statistical dependence is important primarily where one desires an estimate of the variability of the expected values."

What is needed then is an experiment or series of experiments designed adequately to test the hypothesis of additivity under a variety of conditions. Such a test would really be determining how closely motion element times adhere to the requirement that they be random variables, for if they are random variables, then mathematical theory says they are additive. A proposal for such an experiment is outlined below.

## Experimental Design

Figure 3 diagrams a work place layout which allows the additivity hypothesis to be tested under many different conditions. The cycle for the right hand is given below: (Part A is basically a pin and part B is basically a sleeve.)

1. Reach to part A.
2. Grasp part A.
3. Move part A to hole No. 3.
4. Position Part A in hole.
5. Release.
6. Reach to part B.
7. Grasp part B.
8. Move part B to hole No. 4.
9. Position part B in hole.
10. Release.
11. Reach to part A in hole No. 3.
12. Grasp part A.
13. Remove part A from hole No. 3.
14. Move part A to part B in hole No. 4.
15. Position part A in part B.
16. Release.
17. Reach to disposal button.
18. Position finger in button hole.
19. Depress button.

The hypothesis is tested for each set of conditions by comparing measured cycle times from a complete and reduced cycle. The reduced cycle does not include motion elements 11 through 16. This basic physical design allows the following variables to be manipulated:

1. Pacing (self pacing being one level of pacing).
2. Hand use (right, left and both).
3. Discrimination.
4. Difficulty of positioning.
5. Distances of reaches and moves.

The variables could be combined in a factorial experimental design with additivity the hypothesis in every case. The reduced cycle time would be compared with the cycle time predicted from measurements made in the complete cycle.

Pacing is achieved through the dual feeder which presents parts A at desired rates. For the self paced condition parts A are available from the same mechanism but remain available until the subject grasps them. Only one part A is visible at any one time, and the display presented to the subject is identical for all paced and self paced conditions.

Discrimination is introduced as a variable by marking some parts B in a particular way (color, dots, etc). Parts B are available from a rack with the parts arranged so that no extra motions are required to gain control of a particular part. The subject is instructed to select only red parts, or to take any of the parts, etc., for different levels of discrimination.

The variable "difficulty of positioning" is manipulated by varying the cross section of parts and the closeness of fit of the positionings required. Distances are varied by changing the positions of the parts supply. An experiment of this nature should establish whether or not the principle of additivity is valid under the variety of conditions of the experiment. Such experimental work is now under way and the results will be made available when the work has been completed.

The question of element definition has been raised as a key issue in motion standard data. If it can be shown by experiments as outlined above that basic additivity holds, at least under some conditions, then it seems that the next task is to redefine standard data elements into additive sets. One of the important criteria of what elements are should be that of additivity. A system of elements needs to be so defined that for reasonable sequences, cycle lengths, and degrees of complexity, their times are additive sets. Complete unrestricted additivity is not a necessary condition, for some possible sequences are of no practical interest.

## Summary and Conclusion

The potential value of a system of universal standard data is well understood. Its uses in production standards, methods design and analysis, product design, tool design and production control have already been well documented in the literature. The present proposals for standard data systems, however, have never been really accepted or acceptable. The basic objection to the standard data concept has been the question of additivity. This paper reopens this question based upon the view that the hypothesis of additivity has never been tested adequately. Other objections to present proposals have been based upon the inadequacy of basic data presented by proponents. No sound research studies are published which indicate the research methods, results and significance levels of the time data. It occurs to the writer that if universal standard data is ever to gain a place of respect in the engineering professions, certain basic requirements must be established for it. In his view they are:

1. Basic additivity of elements or an acceptable error by ignoring non additivity.
2. A classification or grouping of motion types such that errors generated could be considered negligible. (As discussed by A. J. Rowe.)
3. Data based upon carefully planned experimental designs with full disclosure of methods and results.
4. Data expressed as expected values and variances. This imposes the requirement of obtaining population values for the standard data elements similar to anthropometric data on body size, weight, etc.

This would eliminate the need for a rating factor in generating the data. The presently included rating factor is not only a source of trouble and mistrust, but undoubtedly a considerable error. The need for variances is particularly great in paced operations and for production standards used in production control where output variability is needed.

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# The Standard Process Chart Symbols Need Revision

By Edward L. Page

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While the process chart symbols are not of momentous significance, nevertheless the present standard symbols constitute an unnecessary obstacle and annoyance to the Industrial Engineer, and are a poor reflection on the profession. The situation can be remedied without much difficulty and I believe should be, as soon as possible.

Just why haven't the standard operation and flow process chart symbols, as developed by a special committee of the A.S.M.E. in 1947, been widely adopted in practice? It cannot be claimed that the symbols have not been publicized, since 1947; they have been printed in nearly all publications which deal with process charting, and have even been made up in stencil form. It can hardly be attributed to apathy, as Industrial Engineers are well aware of the advantages of standardization and would not be likely to shun a standard applying to their particular field. Of the many persons I have questioned about the adoption of these standard symbols, nearly all have indicated a neutral or outright negative attitude toward them. In teaching Industrial Management, Motion and Time Study, Plant Layout and Materials Handling Courses, the faults of the present standard symbols have been glaringly apparent.

The basic reason why this standard has not been adopted lies in the fact that the standard has one serious fault. The major symbol, i.e., for transportation, fails to meet three of the five criteria which the standardization committee set up as a guide for determining the symbols! Incidentally, this provides an excellent illustration of how a standard will not be accepted unless it adequately serves the purpose for which it was established.

The criteria used in establishing the symbols is very logical and satisfactory, as anyone understanding the application of process charts will recognize. "The following criteria were accepted by the committee as a guide for the shape of the symbols":[1]

(1) Symbols should be readily distinguished from other symbols
(2) should provide room for writing within, either alone or when combined with other symbols
(3) should combine readily with other symbols
(4) should be used in only one orientation
(5) should be capable of being drawn freehand easily, poor draftsmanship should not result in confusion with another symbol.

[1] A.S.M.E. standard-operation and flow process charts. May, 1947, paragraph 12.

Let us consider the present symbols. The designation of an operation by a circle, and inspection by a square resting on one side, are quite satisfactory. The arrow ⇨ for the transportation, the inverted equilateral triangle for storage and the D for delay are not satisfactory, for one or more reasons which will be explained subsequently.

If the present symbols are not satisfactory, what other symbols can be used which can be easily drawn, readily recognized, combined, and provide space for writing within? In seeking an answer to this question the following becomes apparent. Irregular figures are either difficult to recognize when drawn freehand, are not combinable, lack space for writing within, or take up too much space relative to the other symbols. In selecting regular figures it becomes only a matter of determining how many sides the figure should have. This is soon reduced to the equilateral triangle and a square because figures of more sides are too inefficient or difficult to draw freehand and too difficult to recognize. Therefore, it comes evident that the process chart symbols should be a circle, triangle, and square, and leads to the conclusion that the fourth criteria, orientation, should be dropped in preference to the other criteria.

The past and present transportation symbols are the major weakness of the standard. The original transportation symbol devised by Frank and Lillian Gilbreth, employing a small circle was not readily distinguishable from the operation circle when drawn freehand, it was so small it did not provide adequate space for writing within, and it was not combinable with other symbols. Thus, the need for another symbol was evident. However, the standardization committee selected an arrow, ⇨ for the transportation symbol. This symbol is very difficult to draw freehand, does not provide adequate space for writing within, and is not combinable with other symbols!

A square, standing on its corner, ◇ provides a symbol which is easily drawn freehand, provides space for writing within and can be readily distinguished from other symbols and from the square used for inspection because the process chart lines connecting the symbols would come from the corners rather than the sides. Thus, even a carelessly oriented square could be easily recognized for what it was intended. In addition this symbol permits the direction of the move to be indicated, if desired.

Let us now consider the equilateral triangle used as

the storage symbol. The triangle, when standing on one of its sides is clearly symbolic of a pile of stored material, yet the committee chose to "invert" the triangle, losing its more obvious symbolism. This has not helped the standard.

Finally, let us consider the D symbol used to designate a delay as opposed to a storage. The D, when drawn freehand is not readily distinguished from either a circle or a square. What is more, this additional symbol has tended to confuse rather than simplify the process charting technique. If a delay need be distinguished from a storage, let it be done by placing an appropriate letter within the storage triangle.

Therefore, it is proposed that the standard process chart symbols be revised and made practical by adopting the following symbols in the orientation shown:

○ Operation
◇ Transportation
△ Storage
□ Inspection

It is hoped that after nearly ten years, some constructive steps will be taken to set our own house in order in this area. Since the matter is of such a simple nature it is all the more reason why it should no longer be left in its present confused and unsatisfactory state.


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# I. E. OPPORTUNITIES

*The Columbus, Ohio Chapter has initiated a project designed to provide Industrial Engineering employment information to AIIE members, industrial and educational institutions. It is believed that proper placement of engineers can do much to relieve the engineering manpower shortage. Various items relative to employment will be discussed here in the coming issues, along with listings of representative applicants and positions known to be available. All information furnished to the committee will be kept confidential. The service will be operated as a clearing-house for information; no attempt will be made to classify or screen either applicants or listed openings. This is your service; if you or your employer are interested in using it, please direct your correspondence to Malcolm M. Kreske, P.E., Chairman, I.E. Opportunities Committee, American Institute of Industrial Engineers, Inc., 145 N. High Street, Dept. OP, Columbus 15, Ohio.*

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*P-4* Branch of Military Service needs several I.E.'s with broad background in work measurement, standards, production, cost control, etc.

# New Undergraduate Curriculum in Industrial Engineering*

**By Norman N. Barish**

*Professor and Chairman, Industrial and Management Engineering Department, New York University*

Industrial engineering as a profession has been making great strides in recent years. Its progress in the future will be tremendously affected by the quality of industrial engineering students who will graduate from our colleges. The quality of these graduates will be determined by the caliber of students who are motivated to choose industrial engineering as well as the quality of the course.

Offering a superior program in industrial engineering provides a two-edged sword in promoting the development of better graduates because a superior program will attract higher caliber students who will respond more effectively to the stronger program.

The Industrial and Management Engineering Department at New York University has just completed a thorough re-evaluation of its undergraduate curriculum in industrial engineering. This re-evaluation has resulted in the initiation of changes in emphasis and approach which, when fully developed, it is hoped will provide a stronger education for the industrial engineers of the future.

## Scope of Industrial Engineering

Before presenting a summary of the new program and what it proposes to accomplish, it would be desirable to consider first what is the scope or boundaries of industrial engineering. Every industrial engineer has his own definition of industrial engineering which to some extent is dependent upon his training and experience. There are therefore wide variations in content and emphasis in many definitions of industrial engineering.

However, it might be useful to mention the definition which has been accepted by the American Institute of Industrial Engineers:

> Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials, and equipment. It draws upon specialized knowledge and skills in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems.

The fields in which the industrial engineer will work are varied and diversified. These include areas of activity outside the traditional types of industrial engineering work. The industrial engineer may be called upon to select plant location; lay out a plant for most efficient operation; analyze a proposed or existing product to ascertain the optimum flow sequence for production; determine performance standards for man-machine systems, including quantity, quality, and cost; design systems and organize the administration of controls (production, inventory, quality, and cost); analyze jobs (content and method) to establish the most effective methods and the proper job evaluation; plan and administer programs for analysis of organization and operation; select products, equipment, tools, processes and methods for optimum results.

In designing our new curriculum, we have kept in mind the wide diversity in the types of work in which the industrial engineer will be expected to be proficient as well as the new analytic techniques useful in this work.

## Curriculum Objectives

Our previous industrial engineering program was primarily a mechanical engineering type curriculum with industrial engineering subjects substituted for the more advanced thermodynamics, heat transfer, and machine design courses. It followed to a great extent the more usual pattern throughout the country. This pattern has developed because the industrial engineering curricula have usually evolved out of the mechanical engineering department, in most cases starting as an industrial option in that department.

In re-designing our curriculum, we have kept in mind not only what industrial engineers have been doing in the past and are continuing to do in the present, but also what we hope they will be called upon to do in the future. We would like our graduates to be able to pioneer in the development of new industrial engineering methodologies.

By placing greater emphasis on mathematics and science, the student can acquire greater flexibility in approaching and solving original problems. Mathematical techniques are assuming greater importance in industrial engineering analysis and design. A firm foundation in science is becoming more and more essential to a fuller understanding of industrial and engineering processes.

By establishing rigorous sequences, in depth, in a technical engineering field on an elective basis, skill in the application of engineering methodology can be effectively

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* The following members of the Industrial and Management Engineering Department participated with the writer in the design of this curriculum: H. A. Cozzens, P. Flatow, N. Hauser, W. R. Mullee, D. B. Porter, A. W. Rathe.

developed. Survey and service courses which tend to be descriptive rather than analytical have been eliminated from the curriculum.

### Outline of Curriculum

Our new core curriculum has been designed to provide the industrial engineering student with a sound education in:

—Mathematics and the physical and engineering sciences
—Human behavioral sciences
—Industrial engineering and management disciplines
—General studies and humanities
—Graphic expression

Furthermore, the student may elect to take a technical engineering option by substituting a prescribed engineering course sequence in place of some of the science and mathematics courses in the core curriculum. The following options are offered:

1. Aeronautical
2. Electrical
3. Mechanical
4. Metallurgical
5. Structures and Transportation

It is possible that a chemical option will be established at a later date.

This new curriculum thus provides the industrial engineering student with the choice of a core curriculum in industrial engineering which emphasizes mathematics and science or an engineering option containing a strong sequence of technical courses in depth.

The new curriculum which is described below retains, of course, a large portion of the basic courses intact from its predecessor curriculum.

### Mathematics and Science

The curriculum has been designed to provide the industrial engineering student with a sound education in the mathematical and the physical and engineering sciences common to all or most of the engineering fields. These courses should be as rigorous as to content and standard as those taken by students following other engineering curricula so as to provide the industrial engineer with a maximum ability to handle a variety of technical engineering problems.

The core curriculum calls for the following courses in the mathematical and physical sciences:

| | *Credits* |
|---|---|
| Mathematics I, II, and III (3 semesters) | 12 |
| Differential Equations | 3 |
| Advanced Calculus I & II (2 semesters) | 6 |
| Mathematics Total | 21 |
| General Chemistry | 4 |
| General Chemistry Laboratory | 4 |
| Theoretical Chemistry[1] | 6 |
| Chemistry Total | 14 |
| Mechanics, Heat, and Sound | 4 |
| Mechanics, Heat, and Sound Laboratory | 1 |
| Light, Magnetism, and Electricity | 4 |
| Light, Magnetism, and Electrical Laboratory | 1 |
| Modern Physics[1] (2 semesters) | 6 |
| Physics Total | 16 |
| Electric Circuits | 3 |
| Electric Circuits Laboratory | 1 |
| Statics | 3 |
| Dynamics | 3 |
| Mechanics of Materials | 4 |
| Fluid Mechanics | 3 |
| Materials Testing Laboratory | ½ |
| Engineering Materials | 3 |
| Engineering Science Total | 20½ |
| Mathematics and Physical and Engineering Sciences Total | 68½[2] |

### Behavorial Sciences

The curriculum should provide the industrial engineering student with training in the human behavorial sciences. Industrial engineering involves the design, evaluation, testing, improvement, and installation of systems in which the human as well as the machine components are significant factors in the effectiveness of system performance. Some rigorous training in basic behavorial science is desirable to give the industrial engineering student a background for applied work as well as to improve his ability to perform experimental research with systems involving human behavior.

The following courses in this area are included in the curriculum:

| | *Credits* |
|---|---|
| General and Experimental Psychology (4 semesters) | 12 |
| Human Relations | 2 |
| Human Behavioral Sciences Total | 14 |

The courses in general and experimental psychology are taught by the Psychology Department and are, at the present time, an elective sequence which the student may take as part of his general studies program. It is departmental policy to encourage all of our students to take this psychology sequence and it is anticipated that practically all of our students will do so.

The human relations course is taught by the Industrial Management and Engineering Department.

### Industrial Engineering and Management Disciplines

The curriculum should provide the industrial engineering student with training in the traditional industrial engineering areas as well as in the newer fields such as human engineering, mathematical programming, information

[1] The student elects either theoretical chemistry or modern physics.

[2] New York University operates on the two-semester system (two 15 week semesters per academic year).

processing, operations analysis, etc. Some of the newer disciplines are most effectively taught by integrating them into existing traditional courses. For example, we are presenting a separate course in human engineering, on the graduate level, but at the undergraduate level we will include some elements of the discipline in our methods and motion study course. In the case of mathematical programming and operations analysis, however, we are adding an entirely new undergraduate course, Analytical Methods in Industrial Engineering. Subjects in allied management and personnel psychology fields which are important to successful industrial engineering practice are also included in the curriculum.

The following courses are taught in this area:

| | Credits |
|---|---|
| Manufacturing Tools and Methods | 2 |
| Manufacturing Tools and Methods Laboratory | 1 |
| Mechanical Measurements | 1 |
| Methods and Motion Study | 3 |
| Work Measurement | 2 |
| Factory Planning | 3 |
| Engineering Economics | 3 |
| Analytical Methods in Industrial Engineering | 3 |
| Statistical Methods | 3 |
| Statistical Methods Laboratory | 1 |
| Quality Control | 2 |
| Plant Visits | 1 |
| Technical Speeches and Reports | 1 |
| Labor and Personnel Management | 2 |
| Distribution | 2 |
| Industrial Management | 3 |
| Industrial Engineering and Management Total | 33 |

All of the above courses, except the Manufacturing Tools and Methods and the Mechanical Measurements courses, are taught by the Industrial and Management Engineering Department.

### General Studies and Humanities

The curriculum provides the industrial engineering student with a sequence of general studies courses stressing the humanities and social studies which, in conjunction with his other course work and experience, will foster the development of a truly educated professional man who will be aware of his cultural heritage and zealous to exercise his rights and duties to insure the perpetuation of a free society. (The engineering courses can, in my opinion, be one of the more important tools for accomplishing the purposes of the humanities program. The truly educated professional man is the one who possesses a real understanding of the environment in which he lives. Engineering education can help to develop the student's understanding of the significant technological aspects of his environment.)

The following general studies are included in the curriculum:

| | Credits |
|---|---|
| English Composition and Rhetoric (2 semesters) | 4 |
| Development of Western Civilization (2 semesters) | 6 |
| Literature of Western Civilization (2 semesters) | 6 |
| Fundamentals of Political Science | 2 |
| Fundamentals of Economic Analysis | 2 |
| Speech | 1 |
| General Studies Electives | 12 |
| General Studies and Humanities Total | 33 |

The general studies elective of a 12 point sequence was previously mentioned in discussing the human behavorial sciences. We expect practically all of our students to take a psychology sequence.

### Graphic Expression

An engineer is frequently required to use graphical methods for communicating ideas in analyzing a problem. The following courses are therefore taken by industrial engineering students to develop their ability to express themselves graphically and to visualize spatial relationships.

| | Credits |
|---|---|
| Engineering Drawing | 3 |
| Descriptive Geometry | 2 |
| Graphic Total | 5 |

### Technical Engineering Options

The core program which has just been presented provides a curriculum to meet the needs of the industrial engineering student who desires a strong background in mathematics, science, and engineering science, but does not wish to specialize in one technical area. This curriculum is intended for students who would be concerned with the more mathematical, statistical, and scientific aspects of industrial engineering.

The aeronautical, electrical, mechanical, metallurgical, and structures and transportation options have been designed so that the industrial engineering student can choose to specialize in different technical fields depending upon his aptitudes and work interest. He can select one of several strong sequences of courses. Thus, a man who intended to do industrial engineering type work in the electrical industry might choose the electrical option. He might also choose this option if he were interested in the applications of data processing equipment to industrial engineering and managerial and business systems problems. If he were interested in industrial engineering type work in the metals industries, he might choose the metallurgical option.

The courses in the various options are described below: *Aeronautical Option* students electing the aeronautical option substitute:

| | Credits |
|---|---|
| Introductory Aeronautics | 2 |
| Aircraft Design | 3 |
| Aircraft Stress Analysis (2 semesters) | 4 |
| Aerodynamics (2 semesters) | 6 |
| Applied Mechanics | 3 |
| | 18 |

In place of:

| | Credits |
|---|---|
| Advanced Calculus (2 semesters) | 6 |
| Engineering Materials | 3 |
| Modern Physics or Theoretical Chemistry (2 semesters) | 6 |
| | 15 |

*Electrical Option* students electing the electrical option substitute:

| | Credits |
|---|---|
| Principles of Electrical Engineering | 3 |
| Principles of Electrical Engineering Laboratory | 1 |
| Electric Circuits I (for electrical engineering students) | 3 |
| Electric Circuits Laboratory I (for electrical engineering students) | 2 |
| Engineering Electronics I & II (2 semesters) | 6 |
| Engineering Electronics Laboratory I & II (2 semesters) | 3 |
| | 18 |

In place of:

| | Credits |
|---|---|
| Electric Circuits (for non-electrical engineering students) | 3 |
| Electric Circuits Laboratory (for non-electrical engineering students) | 1 |
| Advanced Calculus (1 semester) | 3 |
| Fluid Mechanics | 3 |
| Modern Physics or Theoretical Chemistry (2 semesters) | 6 |
| | 16 |

*Mechanical Option* students electing the mechanical option substitute:

| | Credits |
|---|---|
| Applied Kinematics | 3 |
| Machine Design | 4 |
| Thermodynamics | 6 |
| Thermodynamics Laboratory | 1 |
| Heat Transfer | 2 |
| | 16 |

In place of:

| | Credits |
|---|---|
| Advanced Calculus (2 semesters) | 6 |
| Modern Physics or Theoretical Chemistry (2 semesters) | 6 |
| | 12 |

*Metallurgical Option* students electing the metallurgical option substitute:

| | Credits |
|---|---|
| Quantitative Analysis | 3 |
| Nature of Solid State | 2 |
| Physical Metallurgy | 3 |
| Metallurgy Laboratory (2 semesters) | 2 |
| Metal Technology | 3 |
| Mechanical Metallurgy | 3 |
| Production of Metals or Physics of Metals | 2 or 3 |
| | 18 or 19 |

In place of:

| | Credits |
|---|---|
| Engineering Materials (for non-metallurgical engineering students) | 3 |
| Fluid Mechanics | 3 |
| Advanced Calculus (2 semesters) | 6 |
| Modern Physics or Theoretical Chemistry (2 semesters) | 6 |
| | 18 |

*Structures and Transportation Option* students electing the structures and transportation option substitute:

| | Credits |
|---|---|
| Structural Analysis I & II (2 semesters) | 6 |
| Structural Design | 3 |
| Reinforced Concrete Structures | 3 |
| Foundations and Soil Mechanics | 4 |
| Surveying | 4 |
| Topographic and Hydrographic Surveying (at summer camp) | 3 |
| Transportation Engineering | 3 |
| | 26 |

In place of:

| | Credits |
|---|---|
| Advanced Calculus (2 semesters) | 6 |
| Manufacturing Tools and Methods | 2 |
| Mechanical Measurements | 1 |
| Engineering Materials | 3 |
| Modern Physics or Theoretical Chemistry (2 semesters) | 6 |
| | 18 |

## Elimination of Survey Type Courses

In our new industrial engineering curriculum we have eliminated survey type courses in the various engineering fields and substituted in their place either mathematics or science courses in the core program or, in the options, basic courses which are the same as those taken by the students majoring in the technical engineering field.

The sequences of courses, in depth, in each technical option were chosen on the basis of recommendations from the various technical departments involved. The courses taken by the industrial engineering student thus provide the same discipline in engineering analysis, design, and problem solving. In this way, it is anticipated that if a student should change his mind and become more interested in the technical rather than the industrial applications, he will generally be prepared to take graduate work in his technical specialty, although the department may sometimes require additional undergraduate prerequisites for individual graduate courses.

## Summary

The above outlined curriculum is developmental and experimental. Basic courses in mathematics and science are emphasized to give the student breadth of coverage and flexibility in solving original problems. Elective options in various technical specialties are offered to permit specialization in a field of interest to the student. The curriculum is subject to improvement as we gain knowledge through experience. Changes will be required to keep abreast of new developments in technology and industry. Comments on this approach will be sincerely welcomed.

# Operations Research—The Scientists' Invasion of the Business World

By Dr. Dean E. Wooldridge

*President, the Ramo-Wooldridge Corporation*

Anyone who today addresses himself to the subject of operations research feels an almost irresistible urge to start by defining the subject. This is probably because, while he may know what he means by the term, he is not quite sure that the words mean the same thing to everyone else. The need here is to start with some kind of definition of operations research that is suitably tailored to the particular set of prejudices to be promulgated.

## An Example

Rather than start with a formal and presumably uninteresting, suitably slanted definition, an episode of the last war will serve to illustrate good operations research. The episode in question concerns a squadron of bombing planes that was stationed on one of the small islands in the Pacific in 1944. These planes were owned and operated by the Air Force, and the story revolves about some difficulties with the United States Navy. It seems that every once in a while one of the Air Force planes would be shot at, and sometimes hit, by naval vessels close to which the planes had occasion to fly. This might have been considered to be just a normal wartime occurrence if it were not for the fact that the incidence of such unfortunate events was considerably higher for the bombing squadron in question than it was for other squadrons operating in the same general area.

Finally, after some exchange of correspondence back and forth between the Pacific island and Washington, the problem was narrowed down to the low level of reliability of the IFF equipment in the aircraft. To those who are not familiar with this term, IFF is an abbreviation meaning "Interrogate—Friend or Foe". The term refers to a black box in the aircraft that constituted, in effect, a special kind of radio receiver-transmitter combination. When any aircraft was sighted by a Navy ship, the ship would send out a special type of radio signal. If the aircraft in question was equipped with the allied IFF apparatus, then another specially coded signal would be returned to the interrogating ship, indicating that the aircraft in question was friendly; consequently, guns would not be fired. But for some reason, the IFF equipment was not working very frequently for this particular squadron in the Pacific. The routine efforts of maintenance on the Pacific island and the encouragement, and perhaps threats, sent out from Washington didn't improve the situation. Finally an operations research expert was sent to the Pacific island to perform careful detailed analyses, to localize the trouble, and, hopefully, to fix it.

Within about two weeks of the arrival of the operations research expert on the Pacific island, the encounters between the aircraft of that base and Navy ships dropped in a rapid and spectacular fashion, and furthermore, the incidence of such encounters stayed practically at zero for week after week. Finally it was clear that the problem had been completely solved, and word was sent to the operations research expert to return to Washington. Upon his arrival, he was of course warmly greeted by his associates, who gathered around and congratulated him, and were most anxious to learn what unusual feats of analysis, higher mathematics, and electronics design he had been able to accomplish in such a short period of time to produce such a miraculous result. Since operations research men are always modest, objective scientists, the returning hero was not at all hesitant in explaining clearly what he had done. He said, "Well, after I had been there for a week asking questions and analyzing the subject, tracing electronic circuits, and making statistical calculations, I finally discovered what I thought was the problem. To cure it, I stationed a man at the end of the runway each time the aircraft took off, and as each airplane passed, this man held up a big sign that we had painted. This sign carried on it the words, 'Turn on your IFF equipment.' From that time on we had no more difficulty."

The point in telling this story is to direct our attention away from some of the more sophisticated techniques that are occasionally employed by skilled operations research people to arrive at answers to some of the problems they encounter—the use of mathematical models, the Monte Carlo method, the theory of waiting, linear programming, and the like, and to concentrate our attention upon the broad concept of operations research and what it is trying to do for its customer.

## Maximize Effectiveness

The legitimate subject matter for operations research includes almost all aspects of any complex organization of men and/or equipment. In the example of the story, the operations research scientist was a trouble shooter. In some way a section of the complex organization of the Pacific Air Force was not operating as effectively as was

believed reasonable in terms of the over-all objectives of the mission. The basic assignment of the operations research scientist was to find out what was wrong and to make recommendations, whatever they might be, that might somehow improve the effectiveness of the operation. In the example in question, the highest mathematics required for proper solution of the problem was probably arithmetic, and very likely not much of that was needed, although it was likely that the man who was sent out to the Pacific island was fully equipped to deal competently with difficult statistical problems if such had turned out to be the principal points at issue. Conversely, an even less technical solution than the one told in the story might have been the result of the investigation. For example, the answer could have been that it was necessary to fire the Commander of the group. The point of all this is that the subject matter of operations research is very broad—it is the effectiveness of the complex organization of men and machinery in achieving its over-all objectives, whatever they might be.

If you accept the rough but very broad definition of operations research just developed, then you have a right to ask, "What is the difference between the task of the operations research expert and that of the manager of the enterprise? Isn't the manager generally earning his salary on the basis of conducting the operation of the enterprise in such a way as to make it most effective in terms of the over-all company objectives, and isn't it his job to run down inefficiencies and modify operations and procedures as required in order to maximize effectiveness? What is the operations researcher up to when he comes to the manager of a company and asks for an assignment? Is he simply saying to the manager, in effect, 'Anything you can do, I can do better'?"

### To Help Management

These are questions to which those of us who are engaged in the selling of operations research have a very high sensitivity. When such questions are asked, we frequently fall all over ourselves to try to reassure the manager that the last thing in the world that we want to do is to give him the impression that we are criticizing him of inefficient management, or to cause him to feel that we are trying to step in and take over from him the job of managing his company. We then generally go into quite an exposition to show what the differences are between operations research and management in an attempt to prove that what we can do is to supplement the manager, but under no circumstances are we really setting out to do the same thing. We frequently defeat our own purposes with this kind of reaction. A more accurate and much simpler reply to the manager who asks if the operations research people are not representing themselves as being able to do a better job than the manager in some of the functions he is being paid for is just a plain, unembellished "Yes".

Of course, there are some management decision areas that are not very well suited to an operations research approach. It is not likely, for example, that the objective, presumed scientific analysis performed by an operations research team could ever develop convincing arguments to prove to the management of the Salvation Army that they should give up their charitable objectives and go instead into the manufacture of poison gas. In other words, there are certain rules of the game that constitute the reason for existence of the company and its basic aims and ambitions that are not properly the subject matter for objective analysis. Admitting that type of exception, however, it is almost true to say that everything else the manager does in operating a complex organization of people and equipment, and every other kind of decision he makes, are basically suitable subjects for operations research.

Therefore, those of us who are trying to sell operations research should face up to the fact that when we go to a manager with our sales pitch, we are in effect saying to him, "Look, we don't believe that you are managing your company as effectively as it could be managed in terms of your over-all company objectives. Put us on your payroll for a while, and we believe that we can effect an improvement."

### Reactions

There are undoubtedly operations research people who will not go along with this rather blunt interpretation of what it is that operations researchers are trying to sell to business people, but there is little question as to how most managers feel after listening to the propaganda. By and large, if they don't end up being hopelessly confused about what operations research is all about, they generally arrive at the conclusion that what the operations researcher is trying to do is to tell the manager that he isn't doing the best possible job of management and that operations research can improve his performance. This poses the manager with a very interesting problem. The only thing he can be absolutely sure of, if he authorizes operations research activities either by groups within his company or by outside consultants, is that he will end by spending money for their salaries. No one, least of all the legitimate operations research scientist, can or will guarantee in advance that the results will be worth the expenditure.

There are two ways that managers react to this proposition. One type of reaction is simple, straightforward, and to the point. The manager says either to himself or out loud, with or without profanity, something about as follows. "I'm having a hard enough time keeping this company in the black as it is. The last thing in the world I need is to pay some long-haired scientists to come down out of their ivory towers and tell me how to run my business." This point of view no doubt has some merit. It nicely eliminates one decision that the manager would otherwise have to make. It prevents a certain amount of confusion in the organization that always results when operations research teams go to work, and it certainly saves the money that would have to be paid for the salaries of the operations research group. It has only one im-

portant drawback. If the operations research people were right, the company is not going to get the benefit of improved operations.

Fortunately, a great many managers react in an entirely different way to the suggestion that an operations research team can improve the management of their enterprises. Each of this class of managers goes through something like the following process of reasoning. He starts with the observation that he is sitting on top of quite a complex organization involving hundreds or thousands of people. These people are divided into various groups, each group living in accordance with a certain set of rules, regulations, and procedures characteristic of the group and related to the other groups by another set of rules, regulations, and procedures. There are accountants, production control people, manufacturing people, engineers, purchasing people, budgeting groups, and so on. Usually the manager of the enterprise is thoroughly familiar with what goes on in only one or two of these major sub-empires, and he is so busy that he has difficulty in maintaining himself current even with respect to these one or two areas. In all other major areas of activity, the manager knows that he himself does not well understand everything that goes on. From time to time major problems have arisen in the operation of the company that appeared to be localized in one or another of the functional areas. On some of these occasions, the manager has attempted to probe into the activities of one or more of these groups and learn enough about their detailed operations to permit him to form his own personal conclusions as to what his problems were. Usually he has been frustrated by such efforts, primarily because he has encountered such ramifications, complexities, and multiple sets of human and functional interrelationships that he simply could not accomplish his objective of self-education in the limited time he could spend on the matter. But this kind of manager has the recollection of such events in his mind, and he therefore suspects strongly that there are areas in his company where the methods and procedures governing the day-to-day operational and decision-making activities are not well tailored to the special requirements of his company's business.

This kind of manager is by no means rare. He is typical of the managers of nearly all large and many medium-sized enterprises. Such managers feel frustrated about some aspects of their company operations that they are sure are not as efficient as they should be, but they don't know where to turn to get an impartial, objective appraisal that takes account of broad company aims and properly subordinates the local interest, prejudices, and established traditions that may currently govern some of the company activities.

Such a manager does not feel insulted when it is suggested that some of the operations of his company may be less efficient than they should be. Furthermore, since he is still convinced that if he personally could only spare the time to dig into the operations he would be able to turn up with major improvements, it is not hard for him to accept the basic idea that an operations research team might be able to accomplish much the same result. Then, too, he knows that it isn't necessary that the operations research team be composed of the world's greatest geniuses, for he is convinced from his own experience that the application of common sense and reason, combined with a proper appreciation of basic company objectives, can go a long way in generating efficient operational and decision-making methods and procedures.

To sell this type of manager on an operations research program, it is mainly necessary to convince him that the team that can be put on the problem will be composed of competent men of reasonable intelligence who can bring to bear an objective, quantitative approach, and that the team, furthermore, will do its work in a sufficiently smooth and tactful manner so as not to produce too much disruption in the day-to-day affairs of the company. If these conditions can be met and if the price isn't too high, then this type of manager is going to buy operations research.

### The Scientist

Our thesis is that almost any complex business involving lots of people is likely to include procedures, methods and ways of making decisions that are not tailored to the actual over-all company objectives as well as they might be. Any team of resonably intelligent and experienced men, with an objective and quantitative approach to problems can, if given the time and the opportunity, dig into a situation of this sort and turn up with recommendations for improvements that probably will more than pay for the salaries of the operations research team, and occasionally may even result in quite a major increase in the effectiveness of the company.

Operations research has been presented in this way in the hope that it will help clear up a bit of the confusion that sometimes seems to surround this subject. At the same time, however, there may be a little more uncertainty as to the difference between operations research and old-fashioned management consulting. After all, haven't the management consultant firms for years engaged in doing exactly the kind of thing that has been described—going into business and industrial establishments, analyzing their operations, and making recommendations for changes to improve over all effectiveness?

Here again, to be a bit unorthodox from the point of view of the operations research fraternity, management consulting and operations research are terms that have nearly the same meaning. It is well to add, however, that there are some important differences in the work that has been done in the past under the label of management consulting and the work that is going on today more generally under the label of operations research. The essence of the difference has to do with the professional background of the people who are doing management consulting under the name of operations research. The new groups consist largely of people who have trained as scientists. Probably the most important single fact we must know to under-

stand why we are beginning to hear so much about operations research these days and why it is becoming such a powerful new tool of management is that within recent years scientists have decided that the operations of complex aggregations of men and machines, as typified by business and industrial establishments, constitute legitimate subject matter upon which self-respecting scientists can spend their time.

Those who do not have a technical background may find it difficult to appreciate the significance of this remark. This point is really quite vital to an understanding of what is going on in operations research today. The subject matter we must deal with in trying to understand this situation is essentially a certain kind of snobbishness that characterized scientists. If this sounds like harsh criticism, at least I can say that it is self-criticism as much as anything else, for I started my professional career as a Ph.D. in Physics about twenty years ago, and I believe my attitudes were quite typical. When I came out of graduate school clutching my bright and shining Ph.D. degree, I had had ingrained into my thinking the certainty that there were only a few limited fields that were worthy areas of occupation for a Ph.D. in Physics. As a matter of fact, there was some serious question in those days as to whether there was any field that it was really respectable for a physicist to work in except nuclear physics. In those days nuclear physics did not mean atom bombs, of course. It had to do with learning more about the fascinating and rather mysterious laws of nature that governed the construction and behaviour of the nuclei of atoms.

I remember I had to make a difficult and almost degrading personal decision to accept a position with Bell Telephone Laboratories, where, instead of working on nuclear physics, I found myself doing research on various solid state matters—how electrons behave inside of crystals, and the like. This field of research involved quantum mechanical considerations and in other ways was adequately respectable so that I felt no danger of being shunned by my professional contemporaries for accepting such an assignment. However, it was about as far as a self-respecting physicist could go in those days.

**Revelations**

Then came the war. The war had a profound psychological effect upon scientists such as myself, for many of us were plunged into problems of a type that we would never in peacetime have considered to be suitable subjects for us to work on. The results were most interesting. To begin with, because we had a good training in basic fundamentals, we turned out to be fairly effective in such matters as the development of radar, electronic computers, and the like, where the necessity of devising entirely new techniques frequently put technical success completely out of the reach of conventional engineering types of approach. The aspect of the situation that was less predictable and therefore more surprising, however, was that by and large the scientists discovered that this work was interesting and challenging. Pretty soon we learned that the job of inventing radar and computing equipment contained problems that were every bit as difficult and as fascinating to solve as the problems associated with atomic nuclei or solid state physics. This, let me emphasize, was quite a revelation to many of us.

As the war went on, this broadening process continued. Pretty soon, we found ourselves involved not only in the design of new equipment, but also in the problems associated with the use of that equipment in military establishments. We had to concern ourselves with the necessity of providing output data from the equipment that human beings could understand and deal with, perhaps as they were flying fast aircraft. We had to concern ourselves with the problems of maintenance and reliability and with complicated practical problems of logistics and supply. We found ourselves also involved in sales activities, whereby we had to present to basically non-technical people what it was we were trying to do and why we should be permitted to do it. And so it was that literally thousands of men trained as scientists or research engineers, who normally would never have considered working in other than a few highly technical areas, were forced by the exigencies of war to see some of the outside world and to learn that they could find interesting and challenging problems in broad operational situations in which the purely technical content might be fairly small. Now the individuals who went through that experience have, as a consequence, been available for a broad range of assignments since the war.

But something perhaps even more important than that has occurred. Because of the influence that these men have had on the curricula and on the students of the universities where some of them have gone back to work and to teach, and the influence they have exerted through professional societies and the many other ways by means of which scientists keep in touch with one another, the general attitude toward life with which new scientists start out into the world is now quite different than it was before the war.

The effect of this whole process has been quite revolutionary. One of the important practical results is that since the war major weapons systems development projects have come along rapidly because good scientifically trained people have been willing to work on these programs. The consequence of greatest significance for this discussion, however, is that today a man trained as a scientist can still hold up his head professionally and not be looked down upon by his contemporaries if he chooses to go into opertions research and concentrate his scientific training on the analysis and solution of problems that arise in large human organizations. Such a situation, unthinkable a few years ago, is a direct consequence of the processes set in motion during World War II.

What is new about management consulting or operations researeh, then, is that scientists have begun to get into it. It just happens that scientists like the name operations research better than they do management consulting. (We scientists have not entirely lost our snobbishness, even yet.)

Of what significance to the management of companies is this entry of the scientist into his domain? Is there something here that really presages a higher caliber of management consulting than has been available in the past? Or is all of this talk about operations research simply a consequence of the scientist trying to pat himself on the back? Perhaps there is some of the latter in the picture, but there is also good solid reason for management to be happy about the increasing availability of scientists for operations research assignments.

**Objectivity**

The scientifically trained man brings to business management several very important qualities. The first of these qualities is professional objectivity. One of the traditions that has been pounded into the head of everyone who emerges as a graduate scientist from a legitimate institution is that he must try to be objective in his approach. He must avoid depending upon authoritative opinions of others as his reasons for conclusions. He must scrutinize the raw data on which conclusions have been based. He must painstakingly check the logic at every stage of the game before he arrives at his own conclusion.

There are two admissions that must be made in connection with the objectivity of scientists. The first is that of course scientists have no monopoly on objectivity. Most good managers are pretty objective also. The second admission is that scientists don't always apply this professional objectivity to their politics or their private lives. However, this is by no means the only instance of a class of men who operate their business in accordance with very rigid professional rules and standards, but who do not always carry over such professional rules to their personal lives.

Scientists are no different than other people in these respects. The important thing is that in their professional lives they are heavily indoctrinated with the idea of objectivity. The standing that they have among their associates depends in a major way upon whether their work gives evidence of an unprejudiced, carefully substantiated objective approach. Most other classes of people are not subject to the same kinds of professional compulsions to be objective as are the scientists. As a consequence, on the average, the scientifically trained investigator of a business or industrial operation does a better job than others in separating fact from opinion and in arriving at conclusions that are properly related to the actual state of affairs under study.

**Quantitativeness**

A second attribute that is common to scientifically trained people is that of quantitativeness. The scientist is trained to work with magnitudes and not just with qualitative effects. The scientist typically is confronted with situations in which a variety of physical phenomena occur simultaneously. He learns at an early date that the proper approach to any new problem is first to determine which factors are the major ones and which are the minor ones, and then to devote his principal attention to the important factors. A qualified scientist does not seize upon a narrow aspect of a problem that accounts for 10% of the phenomena he is investigating and concentrate his attention on that. He looks for the aspect of the situation that accounts for 90% of the phenomena and concentrates his attention upon that instead.

Such a quantitative approach is also not unique to scientists, but they have the advantage of having had this sort of thing drummed into them in their formal training and in their professional experiences. For years and years, they have spent most of their time in arriving at quantitative, numerical solutions to complex problems. Such a quantitative approach is of great importance in the analysis and resolution of operational and procedural problems that arise in a complex human society. The one thing that can usually be depended upon is that the problem that really is responsible for inefficient operations will be camouflaged by a large number of interrelated matters that can be differentiated from the major issue only by a quantitative evaluation of their relative effects on the attainment of the over-all objectives of the operation under study.

**Capacity**

Another pertinent quality of the scientist is his capacity for studying and learning new fields. In his day-to-day activities, the scientist has frequent need to acquire an understanding of the important elements of some new subject that he may never before have encountered. This capacity is the principal tool by means of which operations research scientists, whose past training may not have included business and industrial methods and procedures, have been able to demonstrate an ability to equip themselves with a good understanding of these nontechnical matters in what sometimes seems to non-scientists to be a remarkably short time.

There is one other advantage many scientists have that, when added to these other points, gives them an unusually favorable position for certain kinds of management consulting activities. As everyone today knows, we are in the early stages of what will within the next twenty years begin to look like a second industrial revolution, characterized by the wide-scale application to business and industry of automation techniques, both for the operation of factories and the handling of data processing assignments. The equipment that is being developed and applied to these tasks is, for the most part, of a highly complex character, and it is primarily electronic in nature. It just so happens that the broadening experience that so many scientists went through during the last war was accomplished in connection with the development of precisely these electronic techniques that are now beginning to be applied to business and industry. This was especially true of physical scientists and electronic research engineers who today comprise one of the most important new classes of professional entrants into the field of operations research. But it is in the application of some of these newer tools of automation and data-processing that an important

part of the growing need for operations research arises. While the manager of a company may or may not decide in favor of an operations research program in the normal course of his business, he has practically no alternative on the occasion of introducing the newer techniques of automation. The very nature of these new powerful tools frequently makes operational procedures simple that were completely impractical before, and at the same time practically requires the elimination of some procedures that in the past were reasonably efficient.

And so, not only does the objective quantitative approach that results from his professional training put the scientist in an unusually favorable position to be effective in operations research, but also the growing impact of automation techniques in business and industry places an unusual premium on the physical scientist who can deal effectively with the newer electronics techniques, as well as with generalized operation problems.

## Summary

By thinking of operations research as simply a quantitative objective approach to the solution of almost any complex management problem, and in minimizing the differences in meanings between the terms management consulting and operations research, the situation has been consciously and deliberately oversimplified. On the other hand, any generalizations have been much more nearly right than wrong, and by employing them it was hoped to succeed in clearing up some of the confusion that seems to surround this much discussed and little understood subject of operations research.

The principal points that have been made, in addition to the approximate synonymity of the term operations research with quantitative objective analysis of management problems, have been two in number. The first was that the thing that is new in this field of management consulting or operations research is that scientists have decided that such activities are respectable and, as a consequence, are getting into the field in large numbers.

The second point was that this is a good thing. As a class, scientists do a better job than most people of separating the major and minor factors in a complex operational situation and applying to them an objective quantitative analysis to arrive at recommendations for company procedures or decision-making methods that best serve the major over-all objectives of the organization. In the special class of situations which may be expected from now on to be the source of a steadily increasing fraction of operations research requirements, arising out of the application of automation techniques to business and industry, operations research groups containing physical scientists or electronic research engineers should be uniquely productive.

The scientist has now decided that the business man is a respectable partner. There are some indications that the business man is willing to be wooed and won. If a marriage does indeed result, there is every likelihood that the union will be a happy and fertile one.

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**Mathematicians**
**Engineers**

*Ramo-Wooldridge has several opportunities for individuals experienced in:*

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Analysis of business data processing systems using appropriate management sciences techniques. Experience required in the application of electronic data processing equipment to complex business systems.

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# Wage Incentives for Inspection

**By Fred H. Lambrou**

*Chief Industrial Engineer, Gruen Precision Products*

When we speak of wage incentives for inspection we are getting into one of the most controversial and perhaps the toughest branch of incentives for indirect labor. Setting incentives for inspection does not have to be tough. With the proper approach this can be relatively easy.

What often happens with indirect labor, not only with inspection, but with maintenance work, and other similar operations, is that Joe complains, "I can't do the work. There's too much for me!" So we add another inspector. Later, when the work load is reduced, we don't transfer the second man to another section. We keep him on, as it is now accepted that it takes two men to do the job. We don't know if he is needed because we haven't measured the work being done. When there is no measurement of work, there is no basis for decisions as to proper work loads. So what it boils down to is that one of two things can be done. We can keep on adding people to these various jobs not knowing how the work load is distributed, or we can measure the work and put these people on incentive.

Now you may ask, "How do you go about measuring the work of inspection?"

There are several steps to be followed in measuring inspection work:

1. Classify work into two categories:
   a. Directly measured work
   b. Indirectly measured work
2. Set up inspection standards and define them
3. Make preliminary studies and set methods
4. Train the inspectors in the new methods
5. Time the work and establish time standards
6. Establish and apply the quality incentive

### Classify the Work

All inspection work can be classified into two categories:

1. Work which can be measured by direct methods such as 100% inspection and sampling of each lot.
2. Work which can be measured by indirect methods such as patrol inspection and laboratory inspection which services various departments and operations.

The first thing that must be done is to review all inspection work in the plant and classify each into one of the two categories. This is necessary as it gives you the approach to use in the studies and the basis for the application of incentive.

### Set Up Standards

Before any attempt is made to timestudy the job, standards must be established and wherever possible physical measurements and limits clearly defined. Dimensional characteristics are easy to inspect for, as plus and minus tolerances are easily established. When it comes to visual inspection, the problem increases. Take the problem of visual inspection for cleanliness. You say a part that is a little soiled is alright and heavily soiled pieces should be rejected. In between, well it depends how much they are soiled. Unless you set up clear-cut definitions and, if necessary samples, each inspector will establish his own mental standard.

### Make Preliminary Studies

In both directly measured work and indirectly measured work it is necessary to first "methodize" the operation. Preliminary studies are needed so that economical methods can be established. This step is no different than methodizing work for any other type of operation.

### Train the Inspectors

Train the inspectors in using the improved methods in the same manner you would follow in any other type of work. Chances are that this would be more difficult with inspectors as they have been following the older methods a longer period of time.

### Time the Work

I have mentioned previously that inspection jobs can be placed in two categories, namely: directly measured jobs and indirectly measured jobs. Directly measured jobs are no different to time than any other job. By applying the same technique as applied to usual direct labor operations standard times can be easily developed.

### Indirectly Measured Jobs

Those jobs I have classified as indirectly measured are a little more difficult to measure. By indirectly measured jobs I mean jobs such as patrol inspection and inspection in the laboratory that services various departments and operations. What makes these jobs difficult to measure is that there are no definite units that these people work on. Let me illustrate on a directly measured job. Let us say the standard for the inspector is .10 hours per piece. We know how many pieces he inspects so that incentive performance is easy to figure. Compare this with a patrol inspector. The patrol inspector services, let us say, a half dozen operations checking the work coming off these machines on a periodic basis. Here we do not have as definite a unit to measure as we do in the directly measured jobs, therefore we must find some measure using a somewhat different technique.

Let us take patrol inspection and outline how a timestudy man can measure the work being performed and also utilize this to convert into an incentive plan. The procedure is identical to that for directly measured jobs, namely,

1. Set up inspection standards and define them.
2. Make preliminary studies and set methods.
3. Train the inspectors in the new methods.
4. Time the work and establish time standards.

**The fourth category "Time the Work and Establish Time Standards"** is the step that we are concerned with here. We proceed;

1. The timestudy engineer takes continuous all day studies for an entire week, or for a sufficiently long period to get a representative picture. He records the time, operation performed by the inspector, the area serviced, and all other information pertinent to the inspector's work.

2. When sufficient time studies are taken, the timestudy engineer classifies his information into two general categories:

a. The operation serviced by the patrol inspector.
b. The nature of the service.

When this is done, it is found that usually two or three operations make up the major portion of the inspector's time. These groups are called control groups. For each of these groups a ratio can be worked out with the numerator being the hours that the patrol inspector services the patrol operation, and the denominator being the earned hours of the control group being serviced, e.g.

$$\frac{\text{50 allowed hours of inspector}}{\text{5000 earned hours of group services}} = .010$$

The measured ratio is therefore .010. The same is applied for the other control groups and also for the entire overall group that the patrol inspector services. These ratios now tell you how many inspection hours are needed to service these groups. These ratios apply only to that particular level of production. It should be emphasized that this ratio is not constant for all levels of production.

Since the measured ratio decreases as the production level increases due to lot sizes, etc., additional time studies are taken when the production level changes to determine the change in the ratio. After sufficient studies are taken at various levels a curve is plotted, which gives the ratio at all levels of production.

The measured ratio is used for control purposes as well as incentive purposes. Knowing the production level for the given period inspection forecasts can be made for any level of production.

## Quality Incentive

Up to this point we have spoken of incentives based on quantity only. In the case of the patrol inspector the earnings are directly related to the output of the people he services as well as through his additional effort. Although this type of incentive has many benefits, full effectiveness can be derived only when quality as well as quantity is translated into the incentive. This can be done in the form of a variance or a credit and debit calculation. After the quantity has been translated into a percentage earned the quality adjustment is made, using an increase for good quality and a decrease for bad quality.

To obtain the figure for the quality adjustment the following must be done: Outgoing quality checks must be made during each payroll period. By outgoing quality I do not necessarily mean quality going to the customer, but quality going out from the group of operators that these patrol inspectors service. In order to determine the quality adjustment, limits of outgoing quality must be established. In many cases the past records can readily be used for this purpose. By plotting the quality historically a pattern will be found to base the adjustment figure.

Besides the errors we must control the influence of quality, weather, and incentive workmanship. It is often easier for the inspector to reject a piece than to completely inspect it, so what may often happen is good pieces will be rejected. A check must be made by a periodic analysis of rejections and the inspectors debited for good pieces rejected.

The quality adjustment should coincide with the payroll period. If there is a lag between the payroll period and the adjustment for that week the quality adjustment will lose its significance and be ineffective.

Quality plus quantity must be used in any incentive system for inspection. Requirements often change and good control of these changing requirements must be established, otherwise the time studies and the incentive system will be worthless.

## Summary

Incentives for inspection, using good timestudy methods, can effectively work to reduce labor requirements, increase the earnings of the inspectors, decrease costs, and aid supervisors in determining labor requirements and work loads.

To attain these results you need:

1. Classification of the work.
2. Precise and clean-cut written inspection standards and definitions.
3. A review of the methods used by the inspectors, establishment of new methods, and training the inspectors in these new methods.
4. Use of good timestudy techniques.
5. Establishment of a quality incentive as well as a quantity incentive.

Incentives based on these fundamentals are soundly devised. They will help you get rid of earning discrimination and at the same time reduce inspection costs; but more importantly the plan I have tried to explain has a sound foundation based on definitions of the work to be done. Thus, you can revise these definitions with changes in conditions and maintain fairness over a long period of years.

# RECENT READABLES

## AUTOMATION

"Computers Aid in Refinery Economics", by R. S. Donovan & R. W. Shrage, *The Oil and Gas Journal*, page 131, May 28, 1956.

The use of computers in economic planning is discussed. The authors list and discuss the following suggestions to assist those who are considering the use of computers: (1) Select a nucleus group with initiation of computing activity a full-time job; (2) Don't make the initial project something trivial; endow it with importance; (3) Rent the equipment, either on hourly or fulltime basis; (4) If early results are favorable, consider outright purchases of equipment; (5) Operations Research should work closely with computing activity; and (6) Consider expansion of computer group from within, or hire trained people.

"Computers Score on Two Counts", by E. I. Organicig, *The Oil and Gas Journal*, page 162, April 16, 1956.

Electronic computers can revolutionize aspects of process engineering in the natural gasoline industry just as they have in accounting and other data processing fields. In fact, the revolution in process engineering has already begun. The quality and quantity of engineering achievement (productivity) is rising due to the use of electronic computers.

Computers have proved useful on two levels: to help the engineer in setting up his problem and to solve the problem once it is set up. This two-fold quality combined with the ability of the new machines to store and retrieve readily vast amounts of data and instructions attracts us compellingly to the electronic computers for really elaborate calculations.

"Computers Solve Those Basic Refinery Problems", by J. Sherman, *The Oil and Gas Journal*, page 116, May 28, 1956.

Use of a high-speed computer greatly increases the amount of computation which it is practical to perform in the refinery. It puts the refinery in much better position to meet unexpected situations such as equipment breakdown, and liberates the process engineer from tedious calculations and so enables him to be more productive.

"Machines that Run Themselves", by A. R. Gardner, *Dun's Review and Modern Industry*, page 43, May, 1956.

Tape-controlled machines are an old story to the textile industry, but they are new to metalworking, electronics, and many other industries. Wires passing through the punched tape on looms raise and lower threads to reproduce desired woven patterns. Punched and magnetic tapes and cards in new machine tool controls guide cutting heads and position work tables, make it possible to reproduce complex parts faster and more accurately without high-skilled labor.

Automatic controls promise to reduce dependence on the skill of the operator, and to make for better utilization of machine time. They should be especially useful where machining operations are complex; where runs are short or moderate in length and set-up time is critical; and where it is desired to reproduce, at different times or in different plants, a number of identical parts.

Automatic controls will mean new responsibilities for the engineer, the purchasing agent, the materials control department—and the materials supplier. Without an operator to "feel" his way through each workpiece, and adjust feed and speed to compensate for hard and soft spots, it's essential to have materials of uniform quality.

"Operating Problems Yield to Electronic Brain", by J. C. Schneider and R. G. Wright, *The Oil and Gas Journal*, page 168, April 16, 1956.

The card-programmed electronic computer has proved useful in gasoline plant computations. Justification is primarily based on making available calculation methods which could not be applied before and not in direct manpower savings work already being done.

Reducing the calculation load on the engineer has the further benefit of making the engineer available for engineering work.

Thus far, only relatively simple process calculations have been performed on the electronic computer, but solution of more complex problems is planned for the near future.

Six articles on automation are presented in the May issue of *Advanced Management* by six writers with vastly different backgrounds and jobs and attitudes. These articles were selected because they are full of facts, actual cases and analytical surveys on automation; because they express several of the strongest viewpoints on automation; and because each author seems aware of the responsible part he and others will have to play as the momentum of automation increases in the years to come.

The article giving "An Application of Automation" by Carl Demrick, Vice President in charge of Manufacturing of the Chrysler Corporation, sketches an exciting picture of the design, construction, and operation of one of the most fully automated facilities in the automobile industry, always a leader in the development of automation.

The article on "The Economic Aspects of Automation" by Edgar Weinberg, Business Economist in the Bureau of Labor Statistics, U. S. Department of Labor, evaluates the outlook for the growth of automation in the next decade, suggests the effects which it may have on a variety of working conditions, and describes studies which the government is making to cope with industrial dislocations which may result from automation.

The paper by Nathaniel Goldfinger, Economist in the Research Department of the A.F.L.-C.I.O., entitled, "Planned Adjustment to Automation", indicates various ways in which collective bargaining and thus management-labor relations will be influenced by the growth of automation in the years to come.

U.A.W. Shop Steward and Committeeman, Edward Falkowski, in his article on "Automation Versus Model T's", gives striking expression to the feelings of the men and women on our production lines and in our offices whose jobs may be affected tomorrow—next month—or next year—by automated machinery or electronic computers. Who knows when his own job will be buffeted by automation?

In his article on "Human Adjustment to Automation", Arthur Turner of the Technology Project of the Yale Institute of Human Relations, shows us that not only employees but also managers have serious adaptations to make as operations in offices or shops under their management are automated. He points out productive lines for future automation research.

Finally, Erwin Schell brings future management needs and responsibilities arising from automation within our ken in his penetrating analysis of "Industrial Continuum and the Nature of Man".

"The Computer Age: Running Plants by Mathematics", *Business Week*, April 7, 1956.

A running survey of the expanding use of computers in new and varied problem areas of industry. Emphasized in particular is the simulation of complete company setups in the refinery industry, where computers are being employed to systematize over-all company operations. The article also reviews several other recent statistical, decision-making, and top-level commercial uses of computers.

## COST CONTROL

"Cutting Costs through Teamwork", by T. J. Englund, *Modern Materials Handling*, page 107, May, 1956.

Savings of more than $1,500,000 have been realized at Norton Company during the first four years of an organized cost reduction program.

The success of this program is largely due to the high degree of interest and enthusiasm that it stimulates throughout the line and staff supervision. Essentially, the program is based upon the operation of two committees, one of which is made up of top management personnel. The other is a middle management group which acts as a clearing house and steering committee between top management and those who work on the projects.

A setup of this kind has several important advantages in addition to the monetary savings that it produces. It provides an excellent way for management to obtain first-hand information on key projects from the men who actually do the work. It also helps them to keep better informed on the latest thinking of their staff specialists in such areas as product design, methods and new equipment.

## GENERAL

"Electronic Computers Solving Production-Engineering Problems", by C. R. DeCarlo, *Mechanical Engineering*, page 416, May, 1956.

During the past several years, considerable interest has been centered upon the possible use of the electronic automatic digital computer as an instrument in production management. Although in practically all cases the machines were originally installed for engineering and scientific calculations, production managements were soon to realize the possible benefit that might accrue from using such a device in the solution of complex production problems. Most of the large computers procured to date by industry, aside from those to be used in large paper-handling applications, such as life-insurance premium notices, public-utility billing, and integrated accounting operations, are to be used in solving problems affecting real production, inventory, and distribution operations. Case histories of production scheduling and control of shop orders, evaluating work standards and measuring production are discussed.

"Industrial Engineering Organization and Practices", *Conference Board Reports*, Studies in Business Policy No. 78, 56 pages.

The purpose of this study is to show how a cross section of companies have defined and organized Industrial Engineering, and to report on the advantages and disadvantages each company has experienced in its approach. Topics discussed are: (1) Industrial Engineering Functions; (2) Position in Company Organization; (3) Organization of Industrial Engineering; (4) Operating Methods; (5) Outside Assistance; (6) Budgeting and Accounting of Its Functions; and (7) Personnel. Case studies of eight different type companies are used to illustrate the above seven topics.

"Small Business Plans for Profit", by W. L. White, *Advanced Management*, page 5, June, 1956.

The author conducted a survey of owners of small businesses who were asked to state their most important and current problems. Their problems were: (1) Forced to make too many crisis decisions; (2) Need for more knowledge of all phases of management; (3) Over-emphasis of what the owner knows best; (4) Too little time for planning; (5) Inefficient long-range planning; (6) Inability to meet changing business conditions; (7) Inadequate cost control; (8) Unwillingness to share ownership; (9) Inability to determine desirable size; and (10) Lack of knowledge of where to go for help. The author discusses each of the above ten administrative problems and points out various solutions which have proved successful.

## JOB EVALUATION

"Management, Union, Join in Job Evaluation", by R. L. Stutz and H. E. Smalley, *Personnel Journal*, April, 1956.

After instruction in job-evaluation methods by an impartial outsider, representatives of labor and management in a Connecticut company agreed on job descriptions and jointly evaluated 375 jobs. The authors conclude that the unusual technique they describe in this article holds promise as a means of achieving more amicable solutions of wage-rate problems and improved labor-management relations.

## MATERIALS HANDLING

"Containerization: Our Newest Handling Principle", by the Editors, *Modern Materials Handling*, page 111, May, 1956.

Despite the tremendous interest in metal containers and new methods of unitizing and shipping, the applications of some of the old standbys in the packaging field—wooden crates, cleated plywood boxes, bags and fiberboard containers of all types—are constantly growing. And as new developments lower the cost and improve the properties of these products, usage is likely to accelerate. This is Part II of a special report that started in the April issue.

"How Automatic Should Sorting Be", by A. Harvey and S. Tanne, *Modern Materials Handling*, page 127, May, 1956.

The problem of sorting, whether by size, shape, weight, style, destination or other breakdown, occurs throughout industry. Frequently this work, though often aided by mechanical equipment, such as conveyors, is a manual operation. One reason for this is that sorting involves recognition and decision. As someone must perform this operation, it often is combined with the physical handling of the item being sorted.

While this approach may be satisfactory under certain conditions, it also may be slow, wasteful of manpower, and a limiting factor in obtaining maximum utilization of equipment and facilities. Materials handling equipment that separates decision-making from handling and that can sort automatically and simultaneously at several different locations offers interesting possibilities for cost reduction.

"Materials Handling in the Soviet Union", by W. H. Brandt, *Mechanical Engineering*, page 509, June, 1956.

In December, 1955, a team visited the Soviet Union to study automation. The team, chosen by ASME at the request of the State Department, spent two weeks in the Soviet Union. During this time they visited seven factories and four research

institutes. Most of these were in the Moscow area, but trips were taken to Gorki, Stalingrad, and Leningrad, so that time for each visit was rather limited. In most cases, one to two hours were spent in touring the factory or laboratory and one or two hours were spent in discussions with the director and engineering personnel. They showed some basic know-how in materials handling. Best efforts seemed to be concentrated at those points where they were going all-out for automation. This has caused them to neglect improvements in relatively modest engineering effort which should pay handsome returns. In some places they will have to step up rates of production tremendously in order to achieve present-day American standards.

"Scorecard Pinpoints Handling Problems", by D. Farguson, *Modern Materials Handling*, page 135, May, 1956.

An unusual materials handling rating procedure has recently been added to the handling and conservation program at North American Aviation. Departmental performance is evaluated on the basis of the number and seriousness of unsatisfactory handling conditions noted and photographed during periodic inspection tours. The purpose of the ratings is to pinpoint handling conditions detrimental to production so that remedial action can be taken. The results have been a marked month-to-month improvement in many departments—and a further incentive among supervisors and workers to develop better techniques for handling and protection.

## PLANT LAYOUT

"Effective Space Utilization", by Ray Colcord, *Best's Insurance News*, April, 1956.

Efficient office planning can offer an important area for cost reduction, and should be of as much concern to management as warehousing and plant layout, the author states. This article offers a fact-filled primer any company planning group might well consider. Among the points discussed: determination of the site, the work flow pattern in the office, the needed service functions (e.g., cafeteria, lounges, conference facilities, etc.), and future expansion probabilities.

## WAGE INCENTIVES

"Maintenance Gets Premium Pay Plan", by Editors, *Plant Engineering*, page 89, June, 1956.

Much has been done of recent years in the way of cost reduction in maintenance operations in industrial plants. Favorable results may be attributed to work simplification, planning, and record keeping. Relatively little has been done in the application of incentives which can be of benefit financially not only to workers but also to management.

Some may feel that it is rather difficult to set up a workable incentive system for maintenance work. Conditions, of course, vary from plant to plant and complications of various degrees can arise. A lot of little details may enter into the overall picture. However, incentives are being applied to maintenance operations in a number of plants. One such system that has been highly successful had its start in 1948 at a plant in the Buffalo, New York, area. It has paid dividends in the reduction of down-time, improvement of work quality, and increased productivity.

## WORK MEASUREMENT

"Can You Profit From Clerical Work Standards?", by P. M. Grieve, *The Management Review*, page 194, March, 1956.

The use of clerical work standards has grown considerably in recent years among companies employing large clerical staffs. To what degree other companies will develop and use such standards depends primarily on the following factors:

1. The size and nature of the clerical staff.
2. How far the basic programs of methods analysis and work simplification, job evaluation and analysis, supervisor training, and base compensation analysis have been developed and used.
3. How far new office equipment will obviate the need for large clerical staffs doing manual repetitive work of the type to which standards can best be applied.

Like any other management tool, clerical work standards will be increasingly used by American industry as long as the anticipated savings more than equal the anticipated costs, both real and intangible, of developing them.

"Is Small Business Managed?", by Phil Carroll, *Advanced Management*, page 22, June, 1956.

The prime difference between a small business that grows bigger and one that fails is the effective use of "trend lines", which indicate the direction of the business. These trends are not established on the basis of budgets or time periods, but on the basis of work standards which allow weeding out excess costs and enable sound schedules and profit controls to be established for efficient management.

"Physiological Fatigue Factors", by Dr. L. A. Brouha, *Office Executive*, page 11, April, 1956.

The unmeasurable factors which cause stress and fatigue in industry—such as emotional stimuli, boredom, social adjustment, etc.—are certainly more numerous than those which can be measured.

From the general point of view of labor utilization the lower the physiological stress required by a given task, the more people will have the capacities to qualify for it. Therefore, the recruitment of new personnel will be simplified and the employees will be able to continue working at a satisfactory level of efficiency in spite of advancing age.

"Trainee Allowances for Clerical Time Standards", by E. Kessler, *The Office*, page 7, May, 1956.

Measurement through the use of time standards is one of the principal methods employed for better control of clerical operations. In order to accurately and equitably gauge the effectiveness of a department, it is necessary that new employees be measured differently than experienced workers. This can be accomplished by using a calculated trainee allowance.

The Worthington Corporation has developed a method of calculating the allowance which is based on the following factors: (1) Basic functions; (2) Exceptions from routine; (3) Originality required; (4) Frequency of functional cycle; (5) Length of functional cycle; (6) Accuracy; and (7) Dexterity. Points allowed each of these factors are totaled and a training period allowance is then determined.

## BOOKS

*Administering a Conversion to Electronic Accounting, A Case Study*, by H. F. Craig, Division of Research, Graduate School of Business Administration, Harvard University, Boston. 1955. 224 pages. $2.50.

To quote the author of this most interesting book, ". . . this study is concerned with the administrative aspects of the installation and operation of mechanized systems of accounting and recording . . ." in the Commercial Department of a large mutual life insurance company.

This is a study of particular administrative problems connected with the introduction of significant changes in procedures, the resulting effect upon the people who worked in the area in which the change was introduced and how these problems were successfully resolved by the management of the Commercial Department. Attention is focused primarily on the behavior of the group of middle management people directly responsible for administration (i.e., management) of the technical changes. It also provides brief, pertinent de-

scriptions of behavior at top management, supervisory and clerical levels of the organization. The study concludes with analytical observations and a generalized statement of recommendations and conclusions.

*Flow Production*, by F. G. Woollard, Philosophical Library, New York, N.Y. Revised Edition, 1955, 195 pages, $7.50.

Mass production implies the method of making vast quantities of similar articles—simple or complicated—by a series of individual acts which are not necessarily connected with each other. Flow production, on the other hand, envisages the passage of the part from operation to operation in a direct and uninterrupted sequence. Eighteen basic principles are listed: (1) Mass production demands mass consumption; (2) The products of the system must be specialized; (3) The products must be standardized; (4) The products must be simplified; (5) All materials must conform to specifications; (6) All supplies must be delivered to a strict time table; (7) The machine must be continually fed with sound material; (8) A time cycle must be set and maintained; (9) Processing must be progressive and continuous; (10) Operations must be based on motion and time studies; (11) Accuracy of work must be strictly maintained; (12) Long-term planning, based on precise knowledge, is essential; (13) Maintenance must be by anticipation, never by default; (14) Every mechanical aid must be adopted for man and machine; (15) Every activity must be studied for the economic application of power; (16) Information on costs must be promptly available; (17) Machines should be designed to suit the tasks they perform; and (18) The system of production must benefit everyone.

*Front Line Cost Administration*, by W. C. Cooling, Chilton Company, Book Division, Philadelphia, Pennsylvania, 259 pages, $5.00.

The jacket of this text describes a book that should be of vital interest to not only foremen, or first-line supervisors as they are often called, but to middle and top management personnel as well. "The foreman need not be an industrial engineer. But if he is equipped with a solid foundation of industrial engineering facts he not only will increase his value tremendously, but he also will spell the difference between high productivity or mediocre plant operation."

The purpose of the book, then, is to present in clear, understandable terms a series of industrial engineering facts for the foreman's use in administering management's cost control policies.

*Industrial Storeskeeping Manual*, by Benjamin Melnitsky, 1956, Chilton Company, Philadelphia, Pennsylvania, 279 pages, $6.00.

A discussion, illustrated by case histories, of methods for providing adequate stock for production departments while at the same time keeping costs down. The main subjects dealt with include standardization; part numbering and naming; marking; records; storesroom layout; materials handling; receiving, storage, and issuance; protecting stores; and inventory. Classification in part numbering and color codes are briefly treated.

*Shaped Diamond Tool Symposium Papers*, American Society of Tool Engineers, Shaped Diamond Tool Symposium, 10700 Puritan Avenue, Detroit 38, Michigan, $2.00 to ASTE members, $4.00 to non-members. Also available as part of the 1956 Collected Papers at $4.00 to members, or $7.50 to non-members.

This Symposium, co-sponsored by ASTE and Armour Research Foundation, embraces twelve technical papers by world-renowned authorities in the diamond industry. The leatherette-bound library edition presents 120 pages of the latest and most complete information available today on the subject of Shaped Diamond Tools. The subject is covered in the following coordinated discussions: man-made diamonds; how diamond crystallography affects the selection, preparation and design of diamond tools; the industrial diamond and thread and form grinding; suggested standards for diamond tools; uses of industrial diamonds in industry—turning, shaping, boring and reaming operations; special uses, and the proper selection of diamonds for industrial use.

*Proceedings of the Second Annual Computer Applications Symposium, Armour Research Foundation*, Chicago, 1955, $3.00.

A complete reporting of the Second Annual Computer Applications Symposium sponsored by the Armour Research Foundation, covering applications of computers and data processing machines to business and management problems as well as engineering and management problems.

*Proceedings, Automatic Data Processing Conference, Harvard University*, edited by Robert N. Anthony, Graduate School of Business, Harvard University, Boston, 1956, 194 pages, $3.50.

All presentations and discussion are presented. Topics include Basic Principles and Techniques, Centralized vs. Decentralized Organization for Data Processing, Criteria for Selection of Equipment, Case Studies of Applications, and Operations Research and Data Processing.

*Guaranteed Wage & Supplementary Unemployment Pay Plans*, by S. Herbert Unterberger, Commerce Clearing House, Inc., Chicago, 189 pages, $3.50.

This booklet explains the "ins" and "outs" of the guaranteed wage issue—advantages, disadvantages, how a plan works, how to set up a plan, legal problems, operation, costs, and other pertinent factors. The full text of the supplemental unemployment benefit plans of the Ford Motor Company, Continental Can Company, and the American Can Company are presented in the appendix.

*Operations Research—Challenge to Modern Management*, by Gerhard R. Andlinger, et al., Operations Research, Box 825, Army Electronic Proving Ground, Fort Huachuca, Arizona, 1954, 125 pages, $10.00.

Results of a group project by nine second-year students at the Harvard Graduate School of Business Administration are presented. The report is aimed at management, to help them evaluate the potential of Operations Research for specific situations. Opinions were gathered from executives, scientists and operations research analysts, then evaluated and the potential utility of operations research determined.

*Operations Research for Management—Volume Two*, edited by Joseph F. McCloskey and John M. Coppinger, The Johns Hopkins Press, Baltimore, 1956, 563 pages, $8.00.

A continuation of Volume One, bringing the material up to date with additional case histories, and a new section on Information Handling in Organized Groups. A rather complete bibliography on Queueing Theory has also been included.

*Practical Time Study*, by Harold R. Nissley, Hitchcock Publishing Company, Wheaton, Illinois, 1955, 79 pages.

This booklet is a compilation of articles published in MACHINE and TOOL BLUE BOOK, dealing with the practical aspects of time study, incentives and arbitration. A down-to-earth presentation with clever illustrations.

*Personnel Management: a Human Relations Approach*, by William H. Knowles, New York, American Book Company, 1955, 504 pages, $4.50.

The author presents a well-balanced view of industrial relations as a process of adjusting human motives and viewpoints to the needs and structure of a modern industrial organization. The book is well written, realistic through elementary pictures of the present status industrial psychology and personnel practices.

# INSTITUTE INTERESTS

## DALLAS-FT. WORTH CHAPTER

The Dallas-Ft. Worth Chapter under the new officers installed in January has gotten off to a flying start for 1956 with an intensive membership drive and expansion of Chapter activities to serve the needs of its members and industry in the Dallas-Ft. Worth area.

The Board of Directors of last year under the direction of President Jim Bourland had compiled complete job descriptions of all officers to eliminate lag previously experienced in change over of officers. With this out of the way, the new Officers and Directors set down the following general objectives for the coming year and began to work toward them:

1. An intensive membership drive spearheaded by team competition between Dallas and Ft. Worth members.
2. Promotion of the Second Annual Management Forum.
3. A series of Plant visitations for members to local plants.
4. A series of Technical Seminars to serve the needs of members for technical data on Industrial Engineering techniques.
5. The creation of a monthly chapter Newsletter to keep members informed on happenings in the area, to provide news of chapter activities, and to tell what other members were doing.

The first event of the year, the Second Annual Management Forum was held Tuesday, March 20, 1956 in the new Statler Hilton Hotel in Dallas. There were over two hundred registrants for the Forum. The all day program included such notable speakers as Dr. M. R. Lohman, Dean of the Division of Engineering, Oklahoma A. & M. College; Mr. W. W. Overton Jr., Chairman of the Board, Texas Bank and Trust Company of Dallas; Mr. G. K. Johnson, Assistant to the President, Chance Vought Aircraft, Dallas, Texas, and others. The program was followed by a social hour and a banquet with remarks by Mr. J. B. Thomas, President and General Manager, Texas Electric Service Company of Ft. Worth.

Plant visitations so far this year have included The General Motors Assembly Plant in Arlington, Texas, Chance Vought Aircraft plant in Grand Prarie, Texas, and the new Eagle Mountain Power plant of Texas Electric Service Company in Ft. Worth Texas. Contrary to what you might think, the visit to the power plant was both interesting and informative. One section is in operation with another section under construction.

The first of the Technical Seminars was held Monday, July 25, 1956 in Dallas in the Conference room of Texlite. The subject, Data Processing With Punched Cards, was presented by Mr. Les Faulkner of Chance Vought Aircraft. Mr. Faulkner has been associated with the I. B. M. section at Chance Vought for some time and comes well qualified to handle the subject.

The Southwest Chapter, American Society of Safety Engineers annually invites the heads of other Professional Societies in the area to their May meeting. This year our Chapter was represented by our Vice President, Mr. R. H. Lundberg.

Mr. Lundberg also spoke at a meeting of the newly organized Associate Student Chapter of AIIE recently formed on the S. M. U. campus.

All in all, the Dallas-Ft. Worth Chapter has created considerable interest and momentum with engineers in this area as indicated by the fifteen or more applications on file with new members coming in each month.

## CHARLESTON-HUNTINGTON CHAPTER

The Charleston-Huntington Chapter met at the Frederick Hotel in Huntington, West Virginia, on May 24. Mr. Ralph W. Updegraff, Vice-President of the Central Region of AIIE, presented the Organization Charter to the Chapter. The Chapter was organized with 45 Charter Members representing 12 companies in the Charleston-Huntington area. In his charter presentation speech, Mr. Updegraff strongly recommended close chapter participation with the National Organization.

Chapter officers elected for the coming year were: President, C. G. Howard, American Viscose Corporation, Nitro; Vice-President, W. A. Buchanan, ACF Industries, Huntington; Secretary, John Snider, E. I. du Pont de Nemours & Co., Belle; and Treasurer, J. H. Meincer, Owens-Illinois Glass Co., Huntington. Also elected were the following members of the Board of Directors: A. W. Rhodes, Carbide and Carbon Chemicals Company, South Charleston; W. L. Emmert, International Nickel Co., Huntington; W. J. Burns, Houdaille Industries, Huntington; and D. M. Villines, Island Creek Coal Company, Holden, West Virginia.

## LOUISVILLE CHAPTER

The Louisville Chapter has published and is distributing a new personnel roster of its members. The roster is contained in a 4½" x 7½" loose-leaf leatherette binder. The data in this roster consist of a separate page for each member (the member's name, photograph, home address, business or company affiliation, job or position, a brief statement of personal background—education and experience, and his hobbies). The roster will be revised by changing only the applicable pages.

The introductory statement of the roster includes a statement of purpose and definition of industrial engineering, list of National and Chapter officers, list of Chapter activities, and Chapter's Constitution and By-Laws.

The roster is being furnished without costs to the members of the Louisville Chapter, local industrial concerns, and to a limited number of others who indicate a need.

The expense of printing the roster has been underwritten by appropriate advertisements contained on the back side of approximately one-fourth of the pages.

## METROPOLITAN NEW YORK CHAPTER

The chapter held its annual business meeting on May 28th to elect chapter officers for the 1956-57 season. The official ballot, originally distributed to the membership in March, was unanimously elected by the members present. We are happy to announce that next year's activities will be directed by: Board of Governors, James G. Harbilas, Robert T. Livingston, and Alex W. Rathe; President, Henry M. Owades; Executive Vice President, Kurt H. Schaffir; Treasurer, Julius L. Schaefer; Secretary, John B. Bridgewater.

Several items of chapter business followed the election of officers. First, a vote was taken on the chapter constitutional amendments previously distributed to members. All amendments were approved. Then the 1957 Nominating Committee was elected: Manny Weintraub, Bert Hauser and Gene Orloff. These men have the responsibility for developing a slate of officers for 1957-58.

The business portion of the meeting was resumed after a very interesting talk by David Meiklejohn, Treasurer of AMF. (Mr.

Meiklejohn related several examples of business situations in which nonengineering factors determined the final course of action.)

Two awards were presented by the chapter; the Membership Award was won by Jim Harbilas for bringing the largest number of new members into AIIE, and the Achievement Award went to the New Jersey organizing committee for its splendid job in developing a chapter across the river. The Achievement Award was accepted for the organizing committee by Erv Eggimann.

Last but not least, Harv Brock presented the high points of the Report of the Board of Governors. The report indicated growth in all areas of chapter operations: Membership more than doubled, pushing over 300. Courses, meetings, inspection trips, seminars and all other events attracted a larger turnout than in any previous period. Circulation of MetrovIEws has increased sizably. Our finances are in sound condition. These gains are the result of the teamwork and enthusiasm of the members who have given so generously of their time, and of the inspired leadership of our outgoing president, Alex Rathe.

### WINSTON-SALEM CHAPTER

At the May meeting, "The Annual Ladies Night Meeting", Mrs. Madeleine B. Street, Chairman, Housing and Management, School of Home Economics, Woman's College of the University of North Carolina and Miss Bette Allison, Instructor in Housing and Management, School of Home Economics, Woman's College of the University of North Carolina spoke on the subject of Work Simplification in the Home.

Mrs. Street and Miss Allison related how the principles of work simplification, which are used in industry today, can be applied to the home. The use of energy, demonstrating these principles, was presented in pantomine. They also discussed how automation has contributed to the home and pointed out some of its limitations. Slides were shown to illustrate the arrangement of equipment and supplies in the Kitchen.

## BOARD OF TRUSTEES' MEETING

**Washington, D. C.**

**May 18, 1956**

*The Board Of Trustees Of AIIE is the official governing body of your organization. This group meets to conduct business for you twice each year. The official minutes of the May Board of Trustees' meeting are published to keep you informed of AIIE activity.*

President E. L. Slagle called the meeting to order at 9:00 A.M. The following members of the Board were in attendance:

| | |
|---|---|
| E. L. Slagle | President |
| W. N. Egan | N.E. Region, Vice President |
| F. T. Geyer | Treasurer |
| D. G. Malcolm | Past President |
| A. W. Rathe | Board Member-at-Large |
| F. F. Groseclose | Past President |
| H. P. Emerson | S.E. Region, Vice President |
| S. Kyle Reed | Board Member-at-Large |
| G. K. Nadler | M.W. Region, Vice President |
| H. L. Manning | Board Member-at-Large |
| W. G. Ireson | W. Region, Vice President |
| F. D. Macy | S.W. Region, Vice President |
| J. M. Farnbacher | C. Region, Vice President |
| J. L. Southern | Executive Secretary |
| D. A. Trenwith | Business Administrator |

1. *Minutes of October 22, 1955 Board of Trustees Meeting*—Mr. Farnbacher moved these minutes be approved as presented. Seconded by Mr. Manning. Motion passed.

### OLD BUSINESS

2a. *Fellow Nominations*—Mr. Malcolm presented a preliminary study of Fellow awards in the AIIE compared to similar awards by other comparable organizations. AIIE has .2% of total members as Fellows while other organizations have from 1.2% to 3.1%.

Col. Groseclose moved that the Constitution's definition of Fellow (Article IV, Section 2, Par. d) be interpreted to mean that an individual may be considered for the Fellow Award regardless of whether or not he is an Industrial Engineer or a member of the AIIE. Seconded by Mr. Farnbacher. Motion passed.

2b. *Other Old Business.*

2b1. *Conferences and Conventions*—A discussion of the financing of National, Regional and Local Conferences and Conventions resulting in a directive to the Director of National Meetings.

Mr. Malcolm moved that the Director of National Meetings include in the proposed National Meeting Manual the stipulation that 50% of the net profit from regional conferences be retained at National Headquarters to be used for expenses of the Regional Vice President within a budget submitted by him and approved by the Executive Committee. Seconded by Mr. Ireson. Motion passed.

2b2. *Chapter Incorporation*—There was considerable discussion of how to best attack the incorporation problem.

Mr. Farnbacher moved; "In view of the scarcity of information, we ask Dr. Rathe's Committee on Professional Relations to investigate what other professional societies are doing and report as soon as possible on how they handled this problem of incorporation." Seconded by Mr. Geyer. Motion passed after considerable debate.

Mr. Southern agreed to employ an attorney to investigate the legal aspects of the problem in each state involved. The Executive Committee is to recommend action as a result of the findings of Dr. Rathe and Mr. Southern and submit suitable changes in the By-Laws to the Board of Trustees for a mail vote as soon as possible.

### NEW BUSINESS

3a1. *Selection of 1958 Convention Site*—Five chapters presented invitations to the Board to hold the 1958 Convention in their cities. They were—Atlanta, San Francisco, Los Angeles, Chicago and Rochester. Mr. Slagle pointed out that since the Convention could only be awarded to one bidder, the losers would have to realize that there was no reason for them to believe they were rejected for any reason, and should continue to bid for future National Meetings and keep up their participation and hosting of regional meetings.

The Board considered the possibility of holding two National *Conferences* per year and the possibility that the Convention date should be changed—no action was taken.

After two votes, the Los Angeles Chapter was selected as host for the 1958, 9th Annual AIIE Conference and Convention.

3a2. *National Meeting Policy*—Mr. Malcolm moved; "In the period of 1958, we establish annual meetings to be held in conjunction with policies to be determined by the Director of National Meetings." Seconded by Mr. Farnbacher. Passed after considerable discussion.

3b. *Membership Reports*—The Board reviewed the May 1, 1956 Membership Reports. Mr. Nadler moved to accept as presented. Seconded by Mr. Manning. Motion passed.

3c. *Financial Report*—Mr. Geyer discussed the financial report, April 1, 1955 to April 30, 1956 which was also presented in mimeographed form.

Mr. Groseclose moved; the financial report be accepted as read. Mr. Reed seconded. Motion passed.

3c1. *Change in By-Laws*—Dr. Nadler moved; Article V, Section 1 of the By-Laws, which now reads: "The fiscal year shall be the calendar year," be changed to read, "The fiscal year shall be October 1 to September 30." Dr. Rathe seconded. Motion passed.

3d. *Interim Budget*—Mr. Manning moved: "The May 1, 1956 to September 30, 1956 Budget be accepted as presented." Seconded by Mr. Southern. Motion carried.

3e. *Proposed Organization Changes*—President Slagle suggested that the Board of Trustees approve the concept of a First Vice President so that the necessary constitution changes could be submitted to the membership for a vote. The First Vice President to be an assistant to the president and in addition to the proposed full-time Executive Secretary. A very lengthy discussion followed. A motion to approve this concept was defeated after an amendment to reduce the number of Board members-at-large from three to two. Failure of the motion to pass also nullifies the amendment.

Dr. Nadler moved: "The Committee on Organization is to recommend specific authority and/or responsibilities for the Regional Vice-Presidents and the Board Members-at-Large to aid the President by relieving him of some of his direct lines of communication." Seconded by Mr. Manning. Motion carried.

3e. *Resolutions and Awards*—Mr. Southern outlined the proposed jewelry and award presentations and asked for the approval of the Board.

Mr. Manning moved: "The materials collected so far be turned over to the Resolutions and Awards Committee and they be instructed to prepare a proposed policy and procedure for such awards to be approved by the Executive Committee before the next Board of Trustees Meeting." Seconded by Mr. Reed. Motion passed.

3f. *Fellow Awards*—By unanimous action, the Board approved the Executive Committee's recommendations of two Fellow Awards: Col. Frank F. Groseclose and Mr. Harold E. Engstrom.

A third candidate was passed over for later consideration based on findings of a committee to study all the individuals in this candidate's profession.

3g. *Long-Range Planning Committee Report*—Mr. Malcolm reported on the June 17th Meeting of the committee and the symposium at Cornell in October, 1955, and discussed the Industrial Engineering definition approved by that committee and by the Board of Trustees for use in the Opportunity Unlimited Brochure. The Committee also had discussed the possibility of the AIIE participating in cooperative arrangements with such societies as the Operations Research Society and The Institute of Management Sciences. A lengthy discussion of Mr. Malcolm's report and the committee's recommendations followed.

The Board agreed that a thorough study should be made of other societies' experience and policy in affiliating and/or aligning themselves with other groups before the AIIE establishes such policies.

3h. *Professional Relations Committee Report*—Dr. Rathe suggested that his report be passed over since it would be repeated on the Convention floor on Saturday. The Board concurred. Dr. Rathe had three specific proposals on which he desired Board action.

Dr. Nadler moved: "In line with Dr. Rathe's suggestion, the chapters be urged to become members of local engineering councils wherever advisable, so that on a local level we could be in cooperation with the ASME, ASQC and the others." Seconded by Mr. Farnbacher. Motion passed.

Dr. Nadler moved: "In line with Dr. Rathe's suggestion, the chapters be urged to implement the ECPD five year plan in their own community with the advice and consultation of the Professional Relations Committee. Seconded by Mr. Farnbacher. Motion passed.

Dr. Nadler moved: "The Board of Trustees endorse the ECPD Professional Development Program." Seconded by Mr. Southern Motion passed.

3i. *Constitution and By-Laws Changes*—President Slagle discussed the various Constitution and By-Laws changes proposed and passed at the April Executive Committee Meeting.

Mr. Malcolm moved: "The membership be asked to vote on this additional change—Article IV, Section 2, Par. (b) to be effective if the proposed change in Article IV, Section 2, Par. (a) is approved by the membership.".

Article IV, Section 2, Par. (b) to be changed to read:

(b) An Associate member shall be:

1. A graduate of a curriculum as defined by Article IV, Section 2 (a)
2. A person holding a state board "Engineer-in-Training" certificate and who is engaged in industrial engineering practice, or
3. A person who can present proof of education and experience in diversified fields of industrial engineering judged by the National Qualifications Committee under rules established by the Board of Trustees to be the approximate equivalent of the above stated qualifications

Seconded by Mr. Southern. Motion passed.

Dr. Rathe moved: "The introduction of the office of First Vice President and the submission of the necessary changes in the Constitution to the membership for vote." Seconded by Mr. Malcolm. Motion passed.

A motion to limit the Board Members-at-Large to two was defeated.

Dr. Nadler moved: "The office of First Vice President not to become functional until a job description is approved by the Board of Trustees." Seconded by Mr. Southern. Motion passed.

Mr. Southern moved: "The addition of Article V, Section 9 to the By-Laws:

"Regular members or affiliates who shall have reached the age of sixty-five years and who shall have paid regular member dues for not less than twenty-five continuous years, or who shall have paid regular member dues not less than thirty years, shall be exempt from payment of further dues and shall be awarded Life Status. The term Life Status shall not be construed to establish a separate grade of membership."

Seconded by Col. Groseclose. Motion passed.

Col. Groseclose moved: "The addition of Article V, Section 10 to the By-Laws:

"Regular members or affiliates may purchase Life Status at any time by payment of the Senior Membership dues rate at that time multiplied by a figure equal to thirty, less the number of years for which dues have been paid to the AIIE as a regular member or affiliate."

Seconded by Mr. Southern, passed by unanimous consent.

Col. Groseclose moved: "The addition of Article VI, Section 7 to the By-Laws·

"The Journal of Industrial Engineering shall be the official publication of the organization. It will be published bi-monthly under the direction of the Editorial Board and the Editor-in-Chief as appointed by the President of the AIIE with the approval of the Board of Trustees. Each student member, affiliate and regular member shall receive copies of the Journal of Industrial Engineering as a part of his membership under regulations established by the Executive Committee. A portion of the national dues equal in amount to the yearly subscription rate of the Journal shall be apportioned from the national dues rate of each affiliate and regular member. Student members may be assigned special rates since they normally will pay dues rates below the normal subscription rate."

Seconded by Dr. Nadler. Motion passed.

A motion to submit a change in the Constitution to the membership that would remove any paid Executive Secretary from the voting officer roster was tabled. The Board referred the problem to the Constitution Committee.

The remaining items of the constitution to be submitted to the membership for vote as proposed by the Executive Committee were approved by consent of the Board of Trustees.

3j. *Executive Secretary, Paid*—President Slagle reported on a meeting of the Committee designated to search out a suitable applicant for the position of paid Executive Secretary.

3k. *Appointment of Executive Secretary and Assistant Executive-Secretary*—Col. Groseclose moved: "J. L. Southern to continue as Executive Secretary." Seconded by Mr. Farnbacher. Motion passed.

Mr. Farnbacher moved: "Frank Geyer be appointed Assistant Executive Secretary." Seconded by Dr. Nadler. Motion passed.

3l. *Education and Curriculum Committee*—Mr. Ireson suggested that the Education and Curriculum Committees be consolidated into one; the Education Committee. The Board agreed.

Mr. Malcolm moved: "The meeting adjourn." Seconded by Dr. Nadler. Motion passed. Meeting was adjourned at 6:45 P.M.

The next meeting of the Board to be held in October 1956.

# AIIE CHAPTERS

## Northeastern Region

**Pittsburgh, Pennsylvania** (Chapter No. 3)

*Treasurer*—William E. Alexander, 104 Lang Court, Pittsburgh 8, Pa.
*Meetings*—Dates and places vary.

**Metropolitan New York** (Chapter No. 5)

*President*—Henry M. Owades, 1404 Amend Dr., E. Meadow, N. Y.
*Exec. V.P.*—Kurt H. Schaffir, 83-45 116th St., Kew Gardens, N. Y.
*Secretary*—John B. Bridgewater, 253 W. 91st St., New York 24, N. Y.
*Treasurer*—Julius L. Schaefer, 1 South Broadway, White Plains, N. Y.
*V.P. (Membership)*—Eugene Orloff, 751 Walton Ave., Bronx 51, N. Y.
*V.P. (Programs)*—Robert A. Frankel, 434 E. 52nd St., N. Y., N. Y.
*V.P. (Public Relations)*—Walter Grayson, 153-14 73rd Ave., Kew Gardens, N. Y.
*V.P. (Research & Education)*—Emanuel Weintraub, 220-44 75th Ave., Bayside, L. I., N. Y.
*Meetings*—Monthly—4th Monday, Auditorium, National Cash Register, 50 Rockerfeller Plaza.

**Syracuse, New York** (Chapter No. 13)

*President*—Maurice A. English, 201 Falstaff Rd., E. Syracuse, N. Y.
*V.P. (Program-Chairman)*—W. Ernest Dowling, 354 Earl Ave., Oneida, N. Y.
*Secretary*—Joseph B. Puchalski, 339 Boston St., Eastwood Heights, Syracuse, N. Y.
*Treasurer*—Gordon Kellogg, 504 Roxford Rd. So., Lyncourt, N. Y.
*Membership Chairman*—Cortland Parsons, 206 Audubon Rd., Fayetteville, N. Y.
*Program Chairman*—W. Ernest Dowling, 354 Earl Ave., Oneida, N. Y.
*Meetings*—Monthly—1st. Tuesday, American Legion Hall.

**Washington, D. C.** (Chapter No. 14)

*President*—Herbert O. Schwartz, 2818 74th Ave., Kent Village, Hyattsville, Md.
*V.P.*—John A. Nevros, 99 Leesburg Pike, Falls Church, Va.
*Secretary*—Ralph A. Calderone, 1826 Lamont Street, N. W. Washington, D. C.
*Treasurer*—Nelson P. Greller, 2800 Allendale Pl., N. W. Washington, D. C.
*Meetings*—Monthly—2nd Tuesday (except July & August) Place varies.

**Boston, Massachusetts** (Chapter No. 30)

*President*—William Vallette
*Secretary*—Marshall Schneider, 505 Lowell St., Lawrence, Mass.
*Treasurer*—William Wyman
*V.P. (Membership)*—Donald Fishman
*V.P. (Qualifications)*—George Davis
*Meetings*—Monthly—3rd. Monday, Smith House, 500 Memorial Drive.

**Philadelphia, Pennsylvania** (Chapter No. 31)

*President*—Michael Damroth, 465 Colfax Rd., Havertown, Pa.
*V.P.*—George Hoffmeister, 38 Alba Rd., Willow Grove 9, Pa.
*Secretary*—Frederick A. Cline, Jr., 414 No. Hills Ave., North Hills, Pa.
*Treasurer*—Merritt J. Sterling, 3 W. Lodges Lane, Bala Cynwyd, Pa.
*Membership Chairman*—Malcolm F. Miller, 71 Prince Frederick St., Washington Park, King of Prussia, Pa.
*Meetings*—Dates and places vary.

**Baltimore, Maryland** (Chapter No. 42)

*President*—Standley R. Kalin, 7004 Park Heights Ave., Baltimore 15, Md.
*V.P.*—J. Markwood Harp, 147 Wilgate Rd., Owings Mills, Md.
*Secretary & Treasurer*—Paul C. Buck, 310 Garden Rd., Towson 4, Md.
*Meetings*—Monthly—2nd Wednesday, Govans Branch Library.

**Rochester, New York** (Chapter No. 44)

*President*—David R. Andrews, 400 Dellwood Rd., Rochester 16, N. Y.
*V.P.*—James Richardson, 46 Poplar Dr., Rochester, N. Y.
*Secretary*—Freeman Lewis, 32 Woodview Dr., Rochester 11, N. Y.
*Treasurer*—Thornton R. Ferrell, Jr., 109 White Oaks Dr., Rochester 16, N. Y.
*Membership Chairman*—William L. Diehl, 40 Rosecroft St., Rochester 16, N. Y.
*Meetings*—Monthly—4th Thursday, Rundell Memorial Library.

**Southern Tier, New York** (Chapter No. 48)

*President*—C. W. Houston, Corning Glass Works, Corning, N. Y.
*V.P.*—D. F. Ammerman, IBM Corp., Dept. 550, Endicott, N. Y.
*Secretary*—R. Enyedy, R. D. #2, Pine City, New York
*Treasurer*—C. W. Lundstrom, Link Aviation, Inc., Ind. Engr. Dept., Binghamton, N. Y.
*Meetings*—Dates and places vary.

**Niagara Frontier, New York** (Chapter No. 49)

*1st V.P.*—Dario R. Bell, 521 Woodland Dr., Tonawanda, N. Y.
*2nd V.P.*—Allistair Dunn, 73 Parkside Ave., Hamburg, N. Y.
*Corresponding Secretary*—Robert E. Reitz, 222 Avon Rd., Tonawanda, N. Y.
*Treasurer*—Max Steudel, 618 Linwood Ave., Buffalo, N. Y.
*Membership & Qualifications Chairman*—Norman E. Weiler, 115 Newburgh Ave., Buffalo 11, N. Y.
*Meetings*—Dates and places vary.

**Erie, Pennsylvania** (Chapter No. 51)

*President*—Roger M. Soth, Hammermill Paper Co., Erie, Penna.
*V.P.*—Harry A. Felley
*Secretary*—LeVern B. Yochim
*Membership & Qualifications Chairman*—Robert W. Arentson
*Program Chairman*—Victor P. Mayer
*Meetings*—Monthly—3rd, or 4th Wednesday or Thursday, Gannon College Library Building

**Metropolitan New Jersey** (Chapter No. 61)

*President*—Don J. Olsen, P.O. Box 387, Rahway, New Jersey
*Meetings*—Dates and places vary.

**Merrimack Valley** (Chapter 62)

*President*—Russell W. Osborn, Jr., 200 Main Street, Amesbury, Mass.

## Southeastern Region

**Atlanta, Georgia** (Chapter No. 6)

*President*—James T. French, 572 Page Ave., N.E., Atlanta, Ga.
*1st V.P.*—D. M. Pitts, 621 Freyer Dr., Marietta, Ga.
*2nd V.P.*—John Scott, III, 5522 Navajo Trail, Atlanta 19, Ga.
*Treasurer*—Edwin B. Upchurch, 4028 Fama Dr., N.E., Atlanta 6, Ga.
Meetings—Monthly—4th Tuesday, Mammy's Shanty, 1430 Peachtree St., N.W.

**Birmingham, Alabama** (Chapter No. 9)

*President*—Cleveland E. Owen, Box 59, Rt. 2, Trussville, Ala.
*V.P.*—James M. Goodson, 216 Montgomery Lane, Birmingham 9, Ala.
*Treasurer*—Joseph S. Creel, 4619 9th Terrace No., Birmingham, Ala.
*Program Chairman*—T. H. E. Welch, 1700 Vanderbilt Rd., Birmingham, Ala.
*Secretary*—Walter G. Gayle, 1700 Vanderbilt Rd., Birmingham, Ala.
*Meetings*—Monthly—2nd Monday, Bankhead Hotel.

**East Tennessee** (Chapter No. 11)

*President*—H. P. Hassell, Jr., 1824 Kettering Rd., Alcoa, Tenn.
*V.P.*—David A. Overton, P. O. Box P, Oak Ridge, Tenn.
*Secretary*—Howard J. Hicks, Sr., Rt. No. 1, Heiskell, Tenn.
*Treasurer*—Robert C. Krapf, 1614 Branson Ave., Knoxville, Tenn.
*Membership Director*—Chester Z. Kwast, 107 Maple Lane, Oak Ridge, Tenn.
*Program Director*—Ronald W. Boling, 222 Perkins Hall, University of Tennessee, Knoxville, Tenn.
*Meetings*—Monthly—3rd Thursday, University Center.

**Tri-Cities, Tennessee** (Chapter No. 17)

*President*—John I. Cox, Jr., 2105 E. Sevier Ave., Kingsport, Tenn.
*V.P.*—Marvin K. Goodman, Rt. 10, Kingsport, Tenn.
*Secretary*—Robert C. Carlock, 1525 Carolina Ave., Kingsport, Tenn.
*Treasurer*—James A. Kummer, 1518 Waverly Rd., Kingsport, Tenn.
*Membership Chairman*—D. P. Templeton, Jr., 1 Edgewood Village, Kingsport, Tenn.
*Program Chairman*—Marvin K. Goodman, Rt. 10, Kingsport, Tenn.
*Meetings*—Monthly—3rd Wednesday, place varies.

**Winston-Salem, North Carolina** (Chapter No. 21)

*President*—William J. Brock, P. O. Box 5408, Winston Salem, N. C.
*V.P.*—Herman L. Cook
*Secretary*—Harold H. Mathews
*Treasurer*—Marshall G. Bryant
*Membership Chairman*—Richard A. Peller
*Qualification Chairman*—Willard G. Preussel
*Program Chairman*—Herman L. Cook
*Meetings*—Monthly—1st Wednesday and then alternate last Tuesdays & Thursdays beginning with last Tuesday in September. Place varies.

**Savannah, Georgia** (Chapter No. 26)

*President*—Sidney T. Nutting, Jr.
*V.P.*—Rudolph Roessle
*Secretary*—Brooke Reeve, P. O. Box 1007, Savannah, Ga.
*Treasurer*—Darney O. Linthicum, 93 Pinetree Ave., Savannah, Ga.
*Membership Chairman*—Samuel H. Orr
*Program Chairman*—Rudolph Roessle
*Meetings*—Monthly—1st Tuesday, Garden Room, Savannah Gas Co.

**Jacksonville, Florida** (Chapter No. 27)

*President*—Russell M. Proctor, 1716 Mayview Rd., Jacksonville 10, Fla.
*V.P.*—Alton D. Fryer, Jr., 5130 Shirley St., Jacksonville, Fla.
*Secretary-Treasurer*—Tinsley W. Rucker, P. O. Box 2700, Jacksonville, Fla.
*Membership Chairman*—Graham V. White, 153 34th Ave., Jacksonville Beach,
*Qualifications Chairman*—Norman H. McDonald, P. O. Box 4484, Jacksonville,
*Meetings*—Monthly—2nd Thursday (except June-August). Place varies.

**Memphis, Tennessee** (Chapter No. 28)

*President*—George Van Gerbig, 903 Dickinson St., Memphis 7, Tenn.
*V.P. & Program Chairman*—Boyd L. Payne, Kimberly-Clark Corp., North 2nd St., Memphis, Tennessee
*Secretary*—Mrs. Charlotte Ruppelt, Rotary Lift Co., 1054 Kansas, Memphis, Tennessee
*Treasurer*—Leroy L. Leslie, 950 Springdale, Memphis, Tenn.

*Membership & Qualifications Chairman*—J. P. Newell, Jr., 2272 Byrn Road, Memphis, Tenn.
*Meetings*—Monthly—First National Bank, Poplar-Plaza Branch.

**Pensacola, Florida** (Chapter No. 33)

*President*—Henry N. Sherburne, 211 Bainbridge Ave., Warrington, Fla.
*1st V.P. (Membership)*—Henry L. Cantrell, 17 Linda St., Pensacola, Fla.
*2nd V.P. (Program)*—John M. Murray, c/o Vanity Fair Mills, Inc., Monroeville, Ala.
*Secretary*—Aubrey A. James, 114 New Mexico Dr., Oakcrest Subd. Pensacola, Fla.
*Treasurer*—George L. Walters, 841 Bayshore Dr., Warrington, Fla.
*Meetings*—Monthly—1st Tuesday, Martine Restaurant

**Miami, Florida** (Chapter No. 40)

*President*—Louis Greene, 700 Santander Ave., Coral Gables, Fla.
*V.P.*—Robert Holway, 3980 N.W. 64th Ave., Miami Springs, Fla.
*Secretary*—Miss Gerry O'Neil, 1244 Asturia, Coral Gables, Fla.
*Treasurer*—Avery C. Smith, 611 N.E. 51st St., Miami 37, Fla.
*Membership Chairman*—Robert Frye, 60 West 57 St., Hialeah, Fla.
*Program Chairmen*—
Charles Asche, 5670 S.W. 4th St., Miami, Fla.
Miss Gerry O'Neil—address above
Avery C. Smith—address above
*Meetings*—Monthly—3rd Thursday, Pan American World Airways—Executive Offices, 1820 Delaware Parkway.

**Chattanooga, Tennessee** (Chapter No. 54)

*President*—David G. Dall, 315 James Blvd., Signal Mountain, Tenn.
*V.P.*—George J. Awad, 1724 Michell Ave., Chattanooga, Tenn.
*Corresponding Secretary*—C. Philip Wehman, 3926 Forest Highland Dr., Chattanooga, Tenn.
*Recording Secretary*—William D. Switzer, 60 Brainerd Apts., Chattanooga, Tenn.
*Treasurer*—William L. Watt, 829 Texas Ave., Signal Mountain, Tenn.
*Meetings*—Monthly—3rd Thursday, American Legion Hall, Lindsay Ave.

**Macon, Georgia** (Chapter No. 55)

*President*—Gerald Geller, 828 North Garden Terrace, Macon, Ga.
*V.P.*—Benjamin J. Thomas, 1244 Carlisle Ave., Macon, Ga.
*Secretary*—Chester L. Henry, 2532 Vineville Ave., Macon, Ga.
*Treasurer*—Fred W. Heuser, Box 281, Warner Robins, Ga.
*Membership Chairman*—Herbert Grodemange, Winship Gardens, Apt. 5-D, Macon, Ga.
*Qualifications Chairman*—Benjamin J. Thomas, 1244 Carlisle Ave., Macon, Ga.
*Program Chairman*—Fred Muller, 830 Pierce Ave., Macon, Ga.
*Meetings*—Dates and places vary.

## Central Region

**Columbus, Ohio** (Chapter No. 1)

*President*—John F. Roberts, 4066 Kenny Road, Columbus 14, O.
*V.P. (Program Chairman)*—John R. Martin, 178 Loveman Ave., Worthington, O.
*Secretary*—Luther H. Simon, R-3 Springvalley Road, Newark, O.
*Treasurer*—John H. Parks, 4040 Cemetery Road, Hilliards, O.
*Membership Chairman*—Thomas M. Warschauer, 5284 Conklin Dr., Rt. 1, Hilliards, O.
*Meetings*—Monthly—3rd Tuesday, place varies.

**Dayton, Ohio** (Chapter No. 2)

*President*—C. E. McQuiston, c/o The Advance Foundry Co., 107 Seminary Ave., Dayton 3, Ohio
*V.P. (Programs)*—H. E. Martin, 228 Sandhurst Dr., Dayton 5, Ohio
*V.P. (Membership)*—R. Y. Morton, 4037 Roland Circle, Dayton 6, Ohio
*Secretary*—A. C. Meyer, 3304 Lenox Dr., Dayton 9, Ohio
*Treasurer*—K. K. McVey, c/o The Standard Register Co., 126 Albany St., Dayton 1, Ohio
*Meetings*—Monthly—Tuesdays, place varies.

**Cleveland, Ohio** (Chapter No. 7)

*President*—E. J. R. Hudec, c/o Case Institute of Tech., 10900 Euclid Ave., Cleveland 6, Ohio
*V.P.*—Martin C. Miller, c/o Republic Steel Corp., 1101 Republic Bldg., Cleveland 15, Ohio
*Secretary*—Chester Kishel, c/o Fenn College, E. 24th & Euclid Ave., Cleveland 15, Ohio
*Treasurer*—Harry S. Berlin, c/o National Screw & Mfg. Co., 2440 E. 75th St., Cleveland 4, Ohio
*Meetings*—Monthly—1st Thursday, Hotel Cleveland

**Cincinnati, Ohio** (Chapter No. 8)

*President*—Richard D. Dister, Rm. 706 Terrace Plaza Hotel, Cincinnati 2, Ohio
*V.P. (Program Chairman)*—Richard Forberg
*Secretary*—John Biddle
*Treasurer*—Robert J. Topits
*Membership Committee*—P. R. Tolley
*Meetings*—Monthly—3rd Wednesday, Engineering Society Headquarters

**Louisville, Kentucky** (Chapter No. 18)

*President*—Charles D. Eldridge, AIIE, P. O. Box 1264, Louisville 1, Ky.
*1st V.P.*—Robert B. Craig
*2nd V.P.*—Robert L. McCormick
*Treasurer*—John J. Coleman
*Secretary*—Marvin S. Garrett
*Qualifications Chairman*—Edward M. Thoben
*Meetings*—Monthly—3rd Wednesday, Mayflower Hotel.

**Stark County, Ohio** (Chapter No. 19)

*President*—Rollin T. McClain, 201 Locke Ave., S.E., Massillon, Ohio
*V.P.*—Byron E. Davis, 257 Hayes Ave., N.E., Massillon, O.
*Secretary*—Roger F. Kurzen, 1706 Spring Ave., N.E., Canton 4, Ohio
*Treasurer*—Richard F. Cain, Box 142, Magnolia, Ohio
*Membership & Qualifications Chairman*—Fred J. Manchesky, 308 Poplar Ave., N.W., Canton, Ohio
*Meetings*—Monthly—4th Tuesday, Knights Restaurant, Plaza Shopping Center, Canton, Ohio.

**Youngstown, Ohio** (Chapter No. 24)

*President*—P. D. Blair, 124 Benita Ave., Youngstown, Ohio
*V.P.*—C. M. Jenkins, Rockwell Steel Spring Div., Furnace St., New Castle, Pa.
*Secretary*—K. P. DeJohn, 595 Baldwin, Sharon, Pa.
*Treasurer*—G. Nanes, 2101½ Elm St., Youngstown, Ohio
*Membership Chairman*—Charles McFarland, The American Welding & Mfg. Co., Warren, Ohio
*Meetings*—Monthly—3rd Wednesday, place varies.

**Ft. Wayne, Indiana** (Chapter No 34)

*President*—Wm. Caple, Parkview Hospital, 2200 Randalia Dr., Ft. Wayne, Ind.
*V.P.*—Art Hill, 4438 Wilmette St., Ft. Wayne, Ind.
*Secretary*—Grayston M. Cripe, 3928 Meda, Ft. Wayne, Ind.
*Treasurer*—Larry Lenarz, 1629 Colerick St., Ft. Wayne, Ind.
*Corresponding Secretary*—Dick Awbrey, 3933 Bowser Ave., Ft. Wayne, Ind.
*Membership Chairman*—Martin E. Zernick, Gen. Elec. Co., 1635 Broadway, Ft. Wayne, Ind.
*Meetings*—Monthly—1st Monday, place varies.

**Central Indiana** (Chapter No. 35)

*President*—Hewitt H. Young, Dept. of Ind. Engr., Purdue Univ., Lafayette, Ind.
*V.P.*—Nels H. Jansen, Ind. Engr. Dept., R. R. Donnelley & Sons Co., Crawfordsville, Ind.
*Secretary*—Ross W. McCormick, 2511 Elizabeth St., W. Lafayette, Ind.
*Treasurer*—Robert J. Wimmert, Dept. of Ind. Engr., Purdue University, Lafayette, Ind.
*Meetings*—Monthly—3rd Tuesday, Purdue University.

**Toledo, Ohio** (Chapter No. 36)

*President*—Walter L. Miller, Libbey-Owens-Ford Glass Co., East Broadway, Toledo, Ohio
*V.P.*—Larry King, Unitcast Corp., 1414 E. Broadway, Toledo, Ohio
*Treasurer*—John Bush, National Supply Co., 3320 Bishop St., Toledo, Ohio
*Meetings*—Monthly—4th Tuesday, National Supply Company, 3320 Bishop St.

**Detroit, Michigan** (Chapter No. 47)

*President*—Prof. Robert S. Jones, 632 Putnam Ave., Detroit 2, Mich.
*V.P.*—James H. Davis, Aluminum Co. of America, 3311 Dunn Rd., Detroit 11, Mich.
*Secretary*—William P. Hunt, 75 Moross Rd., Grosse Pointe Farms 36, Mich.
*Treasurer*—Luther J. Broyles, 10052 Heyden Court, Detroit 28, Mich.
*Membership Chairman*—Clinton A. Jaycox, 12751 Hemingway, Detroit 39, Mich.
*Qualifications Chairman*—Gerald E. Clark, 213 East Webster, Royal Oak, Mich.
*Program Chairman*—David W. Dodds, 15305 Parkgrove, Detroit 5, Mich.
*Meetings*—Monthly—1st Tuesday, Engineering Societies Of Detroit.

**Akron, Ohio** (Chapter No. 52)

*President*—Thomas A. Kruger
*V.P.*—Stanley J. Mihelick
*Secretary*—Douglas D. Smith, 857 W. South St., Akron 7, Ohio
*Treasurer*—G. W. Timms
*Meetings*—Dates and places vary.

**Calumet, Indiana** (Chapter No. 53)

*President*—P. S. Cochran, 216 Taft St., Gary, Ind.
*V.P.*—R. M. Fissinger, 211 Roosevelt St., Gary, Ind.
*Corresponding Secretary*—H. B. Hunt, Jr., Gen. Amer. Trans. Corp., 4405 Euclid Ave., E. Chicago, Ind.
*Recording Secretary*—L. E. Kollar, 3616 Connecticut, Gary, Ind.
*Treasurer*—C. H. Dorsett, 3020 Kenwood Ave., Hammond, Ind.
*Meetings*—Dates and places vary.

**Charleston-Huntington, West Virginia** (Chapter No. 58)

*President*—Charles G. Howard, American Viscose Corp., Nitro, West Virginia
*V.P. (Program Chairman)*—Walter A. Buchanan, American Car & Foundry Div., 2300 Third Ave., Huntington, W. Va.
*Secretary*—John A. Snider, E. I. DuPont de Nemours, Belle Works, W. Va.
*Treasurer*—John H. Meincer, 1515 Holderby Rd., Huntington 1, W. Va.
*Membership Chairman*—John A. Snider (see above)
*Meetings*—Dates and places vary.

## Midwestern Region

**St. Louis, Missouri** (Chapter No. 16)

*President*—Donald H. Denholm, Chase Bag Co., 5033 Southwest, St. Louis, Missouri
*V.P.*—Martin Bauer, Carter Carburetor, 2840 N. Spring, St. Louis, Mo.
*Secretary*—Owen W. Miller, Dept. of Ind. Engr., Washington University, St. Louis, Missouri
*Treasurer*—Herbert Richter, Cupples Products, 2650 S. Hanley Rd., St. Louis, Missouri
*Membership Chairman*—G. Lumsden, Dow Chemical Co., Madison, Illinois
*Qualifications Chairman*—E. A. Carlson, 1119 S. Berry Rd., Webster Groves 19, Missouri
*Meetings*—Monthly—2nd Wednesday, Town Hall, 6736 Clayton Road.

**Chicago, Illinois** (Chapter No. 25)

*President*—A. E. Aronson, Rt. 2, Box 387, Arlington Hts., Ill.
*V.P.*—J. I. Herlihy, 1624 W. 107th St., Chicago 43, Ill.
*Secretary*—J. G. Cloyd, Republic Steel Corp., 116th St. & Burley Avenue, Chicago 17, Ill.
*Treasurer*—R. P. Konzen, 1455 West 38th St., Chicago 9, Ill.
*Membership Chairman*—G. G. Irwin, 12454 Princeton, Chicago 28, Ill.
*Qualifications Chairman*—J. Russell Kotal, 2841 W. 84th St., Chicago 29, Ill.
*Program Chairman*—T. L. Woolard, 350 E. 22nd St., Chicago 16, Ill.
*Meetings*—Monthly—3rd Wednesday, Western Society Of Engineering.

**Twin City, Minnesota** (Chapter No. 38)

*President*—Robert B. Gunderson, 7432 Stevens Ave., S., Minneapolis, Minn.
*V.P.—Program Chairman*—Donald W. Wray, 4301 Eton Pl., Minneapolis, Minn.
*Secretary*—A. James Ronning, Route 6, St. Paul 9, Minn.

*Treasurer & Membership Chairman*—Joseph B. Lloyd, 244 19th Avenue N., Hopkins, Minn.
*Meetings*—Monthly—3rd Tuesday, place varies.

**Milwaukee, Wisconsin** (Chapter No. 45)

*President*—John J. Schreibeis, Cutler-Hammer, Inc., 315 No. 12th St., Milwaukee, Wis.
*V.P.*—Clarence J. Allen, Cudahy Brothers Co., Cudahy, Wis.
*Secretary*—Jack R. Platten, Continental Can Co., Inc., 4300 N. Port Washington Rd., Milwaukee, Wis.
*Treasurer*—Donald A. Sinke, Square D. Co., 4041 N. Richards St., Milwaukee, Wis.
*Membership Chairman*—Glenn D. Wolfe, Heil Co., 3000 W. Montana, Milwaukee, Wis.
*Program Chairman*—David A. Drewery, Harnischfeger Corp., 4400 W. National Avenue, Milwaukee, Wis.
*Meetings*—Date varies, Marquette University, Room 213, Business Administration Building.

**Mississippi Valley** (Chapter No. 46)

*President*—Larry N. Chambers, 3019 Jefferson St., Davenport, Iowa
*V.P.*—Charles A. Hanson, Ind. Engr. Div., Deere & Co., Moline, Illinois
*Recording Secretary*—Robert Kalen, Oscar Mayer Packing Co., 1337 W. 2nd Street, Davenport, Iowa
*Corresponding Secretary*—Robert Clarke, 456½ Eleventh St., Silvis, Ill.
*Treasurer*—Robert Ohlweiler, 4248 14th Street, Rock Island, Ill.
*Membership Chairman*—Albert Ujlaky, 1506 W. Columbia Ave., Davenport, Iowa
*Program Chairman*—Marvin Johnson, 606 W. 30th St., Davenport, Iowa
*Meetings*—Dates and places vary.

**Wichita, Kansas** (Chapter No. 56)

*President*—S. Donald Miner, 1912 E. Denker, Wichita, Kansas
*V.P.*—Henry Bogardus, 2409 Riverlawn, Wichita, Kansas
*Secretary*—W. B. Cochran, 2815 Glen Oaks Drive, Wichita, Kansas
*Treasurer*—Orville Paige, 2230 S. Ridgewood, Wichita, Kansas
*Membership & Qualifications Chairman*—Dan Ellis, 1302 W. 20th, Wichita, Kansas
*Meetings*—Monthly—1st Tuesday, place varies.

## Southwestern Region

**Dallas-Fort Worth, Texas** (Chapter No. 10)

*President*—A. L. Ziegelmeyer, Jr., P. O. Box 9834, Dallas, Texas
*V.P.*—R. H. Lundberg
*Secretary*—A. W. McCoy
*Treasurer*—R. W. Palmer
*Membership Director*—J. M. Elek
*Qualifications Director*—J. M. Langendoen
*Dallas Program Director*—L. E. Faulkner
*Ft. Worth Program Director*—R. Hammond
*Meetings*—Monthly—1st Wednesday, place varies.

**Tulsa, Oklahoma** (Chapter No. 15)

*President*—Robert O. Greaves, 5916 E. 24th St., Tulsa, Okla.
*V.P.*—Frank Means, 330 E. 11th St., Tulsa, Okla.
*Secretary*—Richard O. Staines, % Service Pipe Line Co., P. O. Box 1979, Tulsa, Okla.
*Treasurer*—Edward Lynn Cunningham, 207 North Boyd, Sapulpa, Oklahoma
*Meetings*—Monthly—2nd Thursday, Student Activities Building, Tulsa University

**Houston, Texas** (Chapter No. 22)

*President*—J. T. Elrod, 5022 Arvilla, Houston, Texas
*V.P.*—Carrington Mason, P. O. Box 1188, Houston, Texas
*Secretary*—E. Carrol Hailey, 7818 Sharondale, Houston, Texas
*Treasurer*—E. J. Walichowski, 6145 Chaffin St., Houston, Tex.
*Membership & Qualifications Chairman*—J. Z. Brewer, 7715 Park Place Blvd., Houston 17, Texas
*Meetings*—Monthly—3rd Wednesday, University of Houston, Library Auditorium.

**San Antonio, Texas** (Chapter No. 39)

*President*—Raymond M. Pall, 114 Rosemont Dr., San Antonio, Tex.
*V.P.*—Robert L. Winston, 1051 Shadwell Dr., San Antonio
*Secretary-Treasurer*—Lt. Carl Bergmann, 1649 W. Craig, San Antonio, Tex.
*Membership Chairman*—William C. Robinson, 112 Riverdale, San Antonio,
*Program Chairman*—Joshua N. Treiman, Box 2568, San Antonio 6, Texas
*Meetings*—Monthly—1st Tuesday, place varies.

**Baton Rouge, Louisiana** (Chapter No. 41)

*President*—B. M. Bryant, 2856 Wenonah St., Baton Rouge, La.
*1st V.P.—Membership Chairman*—A. E. Fitzgerald, 640 Laurel St., Baton Rouge, La.
*2nd V.P.—Program Chairman*—A. L. Friedrichs, 4262 Prescott Rd., Baton Rouge, La.
*Secretary*—A. J. Aguzin, 2729 Iberia St., Baton Rouge, La.
*Treasurer*—H. S. Row, Box 165, Baton Rouge, La.
*Meetings*—Monthly—3rd Monday, place varies.

**Oklahoma City, Oklahoma** (Chapter No. 57)

*President*—Ray M. Crouch, 1222 North Market, Shawnee, Okla.
*V.P.*—Don K. Andrews, 327 N.W. 22nd, Oklahoma City, Okla.
*Secretary*—Ralph Good, 914 N. Kennedy, Shawnee, Okla.
*Treasurer*—C. O. Hollingshead, 2110 N. Union, Shawnee, Okla.
*Membership Chairman*—Norris A. Griffith, 3713 S.E. 24th, Oklahoma City, Okla.
*Meetings*—Dates and places vary.

**East Texas** (Chapter No. 60)

*Secretary-Treas.*—D. G. Letbetter, 435 Lafty Drive, Longview, Texas
*Meetings*—Dates and places vary.

## Western Region

**San Francisco-Oakland, California** (Chapter No. 12)

*President*—R. L. Knighton, Commercial Research Dept., Columbia-Geneva Steel Div., 120 Montgomery St., San Francisco, California
*V.P.*—J. L. Buckwalter, 758 Peralta Ave., Berkeley 7, Calif.
*Secretary*—W. A. Hecht, Ind. Engr. Sec., United Airlines Maintenance Base, San Francisco Internat'l. Airport, San Francisco, Calif.
*Treasurer*—J. G. Ochsner, 1439 Allman St., Oakland 2, Calif.
*Program Chairman*—N. E. Grabstein, Management Analyst, Kaiser Aluminum & Chemical Corp., 1924 Broadway, Oakland, Calif.
*Membership Chairman*—H. F. Downie, Asst. Works Ind. Engr., Columbia-Geneva Steel Div., Pittsburgh, Calif.
*Meetings*—Monthly—1st Thursday, Claremont Hotel.

**Seattle, Washington** (Chapter No. 20)

*President*—Alf J. Rorstad, 16716 S.E. 51th Ave., Bellevue, Washington
*V.P.*—Henry E. Thomson, Jr., 6533 17th Avenue, N.E., Seattle 15, Washington
*Secretary*—Cecil W. Parrott, 4929 Rose St., Seattle 8, Wash.
*Treasurer*—William D. Evans, 4039 S. 106th St., Seattle 88, Wash.
*Membership Chairman*—Eldridge W. Farnsworth, 1800 Taylor Ave., Seattle 9, Washington
*Meetings*—Monthly—1st Wednesday, Seattle Engineering Club.

**Los Angeles, California** (Chapter No. 23)

*President*—Bordon M. Coulter, 127 Sinclair Ave., Glendale 6, Calif.
*1st V.P.*—Arnold A. Cowan, 2755 Colby Avenue, Los Angeles 64, Calif.
*2nd V.P.*—C. Wilson Whitson, 1876 Pepper Dr., Altadena, Calif.
*Secretary (Acting)*—Rogers M. Akers, 860 W. Edna Pl., Covina, Calif.
*Treasurer*—Donald S. Smith, 1382 Wesley Ave., Pasadena, Calif.
*Meetings*—Monthly—2nd Tuesday, Rodger Young Auditorium

**San Diego, California** (Chapter No. 29)

*President*—Lawrence R. Becht, 3133 Gregory St., San Diego 4, California
*V.P.*—Dee Bennett, 825 Ostend Court, San Diego 8, Calif.
*Secretary*—Oliver J. Belzer, 819 Sutter St., San Diego 3, California
*Treasurer*—Val G. Picciotti, 5410 Mary Lane Dr., San Diego 15,
*Meetings*—Monthly—2nd Tuesday, Officer's Club, U. S. Naval Station, 32nd & Main Sts.

**Rocky Mountain, Colorado** (Chapter No. 32)

*President*—E. Don Williams, Jr., 900 Quari, Aurora 8, Colo.
*V.P.*—C. A. Hart, 10000 W. 21 Avenue, Denver, Colo.
*Secretary*—Robert S. Shepler, 2453 So. Xavier, Denver 19,
*Treasurer*—Don N. Sullivan, 8685 W. Bayaud Ave., Lakewood, Colorado
*Membership Chairman*—James E. Stone, 1665 So. Tennyson, Denver 19, Colo.
*Meetings*—Monthly—2nd Tuesday, Cunningham's Restaurant, 1578 S. Broadway, Denver

**Peninsula, California** (Chapter No. 37)

*President*—Alvin Colburn, 11525 Farndon, Mountain View, Calif.
*V.P.*—Richard L. Houk, 1962 Channing Ave., Palo Alto, Calif.
*Secretary*—Max E. Shaffer, 1215 Emerson St., Palo Alto, Calif.
*Treasurer*—Don W. Grider, 841 Tuscaloosa Ave., Atherton, Calif.
*Membership Chairman*—William S. Bennett, 28 W. Santa Inez, San Mateo, California
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